ETHIOPIAN CIVIL SERVICE COLLEGE

Urban Management Masters Programme

# Impact of Vehicle Traffic Congestion in Addis Ababa (The case of Kolfe Sub-City: Total – Ayer Tena Road)

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A Thesis Submitted to the Urban Management Masters Programme, Ethiopian Civil Service College, in Partial Fulfillment of the Requirements for the Award of a Masters Degree in Urban Management.

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# DECLARATIONS

I Yared Haregewoin Registration Number 898/01 do hereby declare that this Thesis is my original work and that it has not been submitted partially or in full by any other person for an award of a degree in any other university/institution.

**Participant:** Yared Haregewoin **Signature……. Date…….**

This Thesis has been submitted for examination with my approval as College supervisor.

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# APPROVAL

The undersigned certify that they have read and hereby recommend to the Ethiopian Civil Service College acceptance of the Thesis submitted by Yared Haregewoin, and entitled *"Impact of Vehicle Traffic Congestion in Addis Ababa (The case of Kolfe sub city: Total – Ayer Tena road)"* in partial fulfillment of the requirements for the award of a Masters Degree in Urban Management.

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## *Abstract*

*Economic development and high urbanization rate has caused many challenges to transportation system of Addis Ababa city. Among others, long travel time (delay), and waste of fuel. Many literatures are indicating that traffic congestion caused by inadequate of infrastructures and poor demand management, such incapable roads, inefficient public transit, poor land-use planning, high travel demand and so on. This paper focuses on the impact of traffic congestion on travel time and vehicles fuel consumption along "Total to Ayer-Tena" road in Addis Ababa city. Both quantitative and qualitative descriptive research design have been used. 270 respondents were drawn randomly from different purposively determined group of the societies. Secondary data was collected from transport organizations. As a result, it has found that traffic congestion caused by many reasons, such as imbalance between the traffic volume and road capacity, inflexible work schedules, inadequate public transport, and poor urban land-use plan are the main reasons. Most journeys along the road are from various peripheral areas of the city to the core areas mainly for daily work and market purposes. On average interval, peoples are traveling between 6 –10 km per day, and most of which are making in 6:30 – 9:30 a.m. and 5:30 – 7:30 p.m. Traffic is highly congested with in this two peak periods. In Addis Ababa, the population of high occupancy vehicles is very low. Surprisingly, evidence shows that the volume of vehicles population will be doubled after 6.3 years, most of which are small personal and private vehicles. Pertaining to the road network coverage of the city, data indicates that the total road length of the city is increasing from time to time. However, it is sluggish in contrasting with the annual vehicles population growth (1.6 %). Vehicles are consuming more fuel in a congested traffic environment than in a free flow condition though its extent is varying from vehicle to vehicle due to their fuel- efficiency and daily total distance traveling. Moreover, regarding travel-time or delay, it is 3 and 5 minutes per vehicle and passenger per trip with in a peak hours respectively. Specifically, the situation is becoming severe at Total intersection due to its narrowness. Lastly, congestion problem can be mitigated through different strategies, such as, apply flextime working time, improve capacity of roads, improving Public transport, experiencing adequate parking arrangements, implement transit-oriented development, and improved access management.*

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## Acronyms /Abbreviations used

| | |
|---|---|
| A.A: | Addis Ababa. |
| AACRA: | Addis Ababa City Road Authority. |
| Adp: | Average delay per passenger |
| Adv: | Average delay per vehicle |
| CBD: | Central Business District. |
| EPTA/hr: | Estimated passengers traveled along the street on average per hour. |
| EVPA/hr: | Estimated vehicles passing along the street on average per hour. |
| Hr: | Hour |
| Km/L: | kilometers per one litter |
| LOS: | Level of Service |
| Lps: | Leaving passengers |
| Lv: | Leaving vehicle |
| Nd: | No date |
| PV/v/hr: | Passengers Volume or carried per vehicle traveled per hour. |
| Pps: | Total number of passengers passed via opposite direction. |
| Pqli : | Number of passengers in each queue of an interval |
| Sv: | Stopping vehicle (including slow moving vehicles) |
| Tdps: | Total delay per passengers |
| Tdv: | Total time delay of all vehicles |
| Tpql | Total number of passengers estimated in the entire process |
| Tpt/hr: | Total number of passengers traveled along the street per hour. |
| TQl: | Total queue length |
| Tvq: | Total number of vehicles with in each queue |
| USA: | United States of America. |
| Vp: | Vehicles passed on opposite direction |
| VTPI: | Victoria Transport Policy Institution |

# CHAPTER ONE: INTRODUCTION

## 1.0 Introduction

As history tell us, cities and traffic have developed parallel side-by-side since human settlements. Though their magnitude or patterns are more complex today, cities still provide access to various social and economic activities, such as services, goods, markets, ideas, network, and these which determines the development of the urban areas. (European Conference of Ministers of Transport, 2007)

Development which is a broad concept, is an outcome of different well integrated elements, like industries, services, education and infrastructures in general and transport system in particular as it play great role in economic growth by facilitating mobility of goods from where they are produced to where they are needed, and people from their resident to different attraction points (Iles, 2005). For instance, the transport sector in European countries constitutes 7% to their GDP and 5% of all employment while having an external cost like road traffic congestion. Road traffic congestion alone cost 1% of their GDP (Delle, 2008). As a result, a better city is a function of sustainable transport system.

Urban economic activities and movements have a direct relationship. Adequate transport system is needed to facilitate a greater choice of the peripheral areas if urban transport provided by the state. Because of most socio-economic activities concentrated in the center of city, many urban mobility problems are created, such as increasing car usage and trips to the central business districts this in turn leads to high demand for parking, urban environmental problem (pollution, noise), and in-abilities to handle these problems results in congestion (Cameron and Krynauw, 2003; Delle, 2008)

Fast growth in urbanization and industrializations demands the use of more vehicles fleet leads to an imbalance between the infrastructures availability and mobility demand. In the third world the roads are narrow or incapable to accommodate a heavy traffic that slow the traffic flow, accompanied by in adequate provision for parking and loading and boarding facilities, sidewalk along the street, and mixed land use (Oluwoye, 2000).

## 1.1 Back Ground of the Study

Congestion, become a common characteristics in urban road transportation system of cities in developing countries which result in high operating cost, loss of users productive time, and more fuel consumption among others (World Bank, 2002).

First: the causes of vehicles traffic congestion are many and interrelated factors, like rapid urbanization that concentrates peoples and economic activities in urban areas or cities. Second; because of different dispersed, but interrelated land use patterns or specializations of the urban areas in some activities, for instance, workforce concentrated in some areas, residential and recreational areas also in other far place that make people to move between them. Third; a mismatch between supply and demand, the problem is sever in peak hours in specific as most people start and end their work at the same time- in the mornings and evenings (Alan, 1995).

Due to numerous factors, congestion is becoming more serious problem in Addis Ababa city from time to time, such as population growth- in addition to natural growth, pull factor that immigrate people from different part of the country to the city in searching for livelihood. To sustain the city, it is clear that these added portions of the society also need transport service to attain their day to day activities. However; the city is unable to cope with the existing high transport services demand. In addition, inefficient land use planning, poor infrastructure, and absence of well traffic management are the major reasons for the problem of traffic congestion. As a result, it is obvious that understand the present situation of vehicles traffic congestion is very important area of consideration in order to make the right decision to solve the issue and thereby sustain seamless traffic flow to contribute to the economic growth of the city is urgent on the top of every thing.

## 1.2 Statement of the Problem

In Africa, vehicle traffic congestion is a new phenomenon. It has an economic cost on the productivity of the cities' communities and economy. Despite the lower car ownership levels, traffic congestion becoming more serious problems in a day to day activity of all

people in all parts of the Addis Ababa city, specifically, in morning and evening peak hours.

Primarily, traffic congestion is an outcome of insufficient traffic management in the city, secondly; insufficient capacity of the roads to cope up with the existing traffic volume, thirdly; inadequate public transport, fixed working time, and poor land-use or transport-land-use planning integration. Fourthly; illegal on-street parking habit are the major problems that lead to vehicles traffic congestion in the city. In addition, long travel time or delay to reach destination that affect business users time productivity, increasing fuel consumption- wastage, are main impact of vehicles congestion which is still prevail. Therefore, this research has been initiated to assess traffic congestion and the impact of the issue on travel time and fuel consumption.

## 1.3 Purpose of the Study

### 1.3.1 General Objective

The main objective of this study is to assess the impact of vehicles traffic congestion in Addis Ababa and suggest some possible countermeasures to the problem.

### 1.3.2 Specific Objective

1. To assess vehicle traffic flow and causes of congestion along the road
2. To examine the road network characteristics
3. To assess the actual on-street parking management
4. To assess the impact of vehicle congestion on travel time and fuel consumption
5. To suggest some possible solution to the problem.

## 1.4 Research Question

- What are characteristics of the current traffic flow and causes for vehicle congestion?
- Is the road capable to cope up with the existing vehicle traffic volume?
- Is on-street vehicle parking management not an impediment for smooth vehicle flow?
- Does vehicle traffic congestion prolongs travel time and affect fuel consumption?
- What are the possible mitigating factors available?

## 1.5 Scope of the Study

The scope of this study is to assess the impact of vehicles congestion along the street of Total to Ayertena in kolfe Sub-City in general and its impact on travel time and fuel consumption, and condition of on-street parking management in particular.

## 1.6 Description of the Study Area

Addis Ababa is located at 9°1′48″N 38°44′24″E 9.03°N 38.74°E and lies at an altitude of 7,546 feet (2,300 meters).Based on the preliminary 2007 census results, Addis Ababa has a total population of 2,738,248, with an estimated area of 530.14 square kilometers (http://en.wikipedia.org/wiki/Addis_Ababa).

Addis Ababa has five main roads that link it with other external Towns of the country. Among them, Addis Ababa - Sebeta main road is one which runs through Kolfe sub-city. The study area is located west of Lideta, south of Addis Ketema, and north-west of Lafto sub-cities. It is just down to south of Tor-Hailoch roundabout, which is *Total intersection* and goes to southwest direction up to *Ayer-Tena* roundabout.

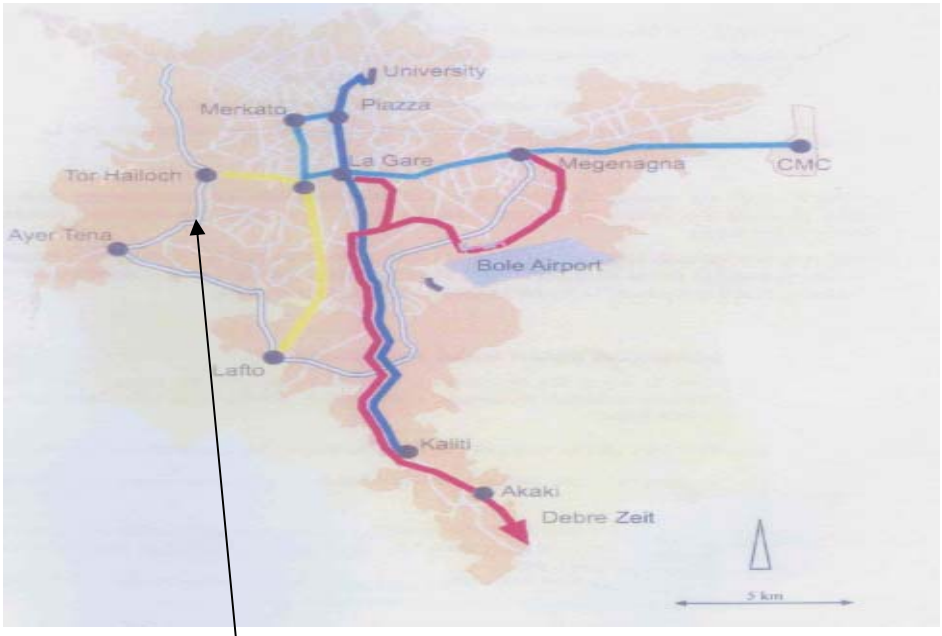



Fig.1 Location of the study area (Total intersection to Ayer-Tena roundabout)

## 1.7 Significance of the Study

It is believed that the out put of this study will add to the existing academic knowledge and enable to understand on the subject matter as it paves the way for further investigation on the issue. Apart from this, it will also benefit other different parties of the societies. First: this research work allows the researcher to assess the current condition and impact of vehicles traffic congestion on the economic activities of the city thereby build academic knowledge and provide base for further carrier improvement. second; it also benefits the host institution-Ethiopian Civil Service College, in attaining its objective "being a center of academic excellence and accelerate the national development" through provision of problem solving research out-put to the policy and decision makers. Moreover, city administration of Addis Ababa can use the finding of this paper for its social and economic policy formulation and right decision making based on true information, so that, the city administration uses its resources efficiently and ensure the city's sustainability by solving the problem of traffic congestion.

## 1.8 Limitation of the Study

There was limitation of time and budget in conducting field survey. In data collection, respondents were un-cooperative in providing information. Specifically, they are not interested to fill an open question. Lack of full documents on road network characteristics and parking management from concerned organizations; on the other hand, variables that are not included in this study, such as traffic signals, skill and discipline of drivers assumed to limit the outcome of the finding on the dependant variables: fuel consumption and delay.

## 1.9 Conceptual Definition of Terms

***A queue:*** is a line of waiting vehicles, such as at street and an intersection (VTPI, 2009).

***Delay (vehicle-hours and person-hours):*** Delay expressed or measured in time per vehicle and per person. For instance, Texas Transportation Institute (2005) stated, as it is a phenomena of a slow speed unlike other normal daytime. Equivalently Corpus Christi Metropolitan Planning Organization (2009) argued that delay is a manner in which journeys are taking long time than what would have been in a normally occurrences.

***Impact:*** Is a result of forceful or a strong effect on something (wordnetweb.princeton website).

***Land-use planning:*** It is a planning carried to identify the optimum uses of land, serve as a basis for the adoption of land use controls (www.bostonoverflightnoisestudy.com/). Land use planning (zoning) determines what parts of urban areas will be used for *particular purpose*, such as residential, commercial area and other. Land-use planning also has a great role in emphasis on transportation planning (http://www.wisegeek.com/).

***Level- of- Service:*** Is one and the most commonly measure that used to assess the level of congestion. LOS measures a traffic volume of a given area qualitatively (Mathew and Krishna, 2007). Six different levels are defined (LOS A, B, C, D, E, and F) with LOS-A representing the best condition and LOS-F representing the worst condition). Many agencies defining congestion in relation with LOS value, either LOS-E or F (Corpus Christi Metropolitan Planning Organization, 2009).

***Parking Management:*** From the web (managed lanes.tamu.edu/products/glossary.stm) is a way that aimed at making better use of available parking supply including favored parking or price discounts. Parking management is a process in which parking area is provided, controlled, regulated, or restricted, and in transportation realm parking policies aim at improving environmental quality and accessibility (Corpus Christi Metropolitan Planning Organization, 2009*)*

***Road capacity:*** Knowingly road capacity is the total volume of traffic that can pass on it freely at once and it is fixed, not changed with traffic volume. To this view, Mathew and Krishna (2007) defined it as it is a maximum volume of traffic, like vehicles, passengers and others accommodated with in a specific time that measured quantitatively, and independent or fixed irrespective of the fluctuating of traffic volume (demand).

***Traffic****:* It is a total aggregation of things, such as pedestrians or vehicles on a particular area or locality during a specified period of time (wordnetweb.princeton website).

***Traffic Congestion:*** Though there is no single definition on vehicle congestion, most common definition by various authors, like European Conference of Ministers Transport (2007), defined vehicle congestion as it is both a physical and relative phenomenon, physically related to the situation of vehicles obstruct each others, for limited road space that reach its full capacity, and a relative phenomenon relating to user expectations in comparison with road system performance. Hook, (1997) and Loop and Perdok, (n.d) have a common view on the meaning of congestion: it is a delay a traveler experiences during his/her journey: that is the difference between the actual realized journey time and a journey time which could have been realized if no traffic congestion had occurred. More specific, in a transportation realm, Texas Transportation Institute, (2005) define vehicles congestion as:

> *An excess of vehicles on apportion of roadway at a particular time resulting in speeds that are slower -sometimes much slower – than normal or "free flow" speeds. Congestion often means stopped or stop-and-go traffic.*

***Vehicles:*** a passageway that transports people/objects (wordnetweb.princeton website).

***Vehicles traffic condition:*** It refers to the mixture of traffic, such as passengers cars: buses, taxis, and trucks on a given road (Mathew and Krishna, 2007).

***Vehicles traffic volume:*** Represents the average number of vehicles unit that passing on a road per time (Poh Lee, et al, 2008).

# CHAPTER TWO

# REVIEW OF RELATED LITERATURE

## 2.0 Introduction

Recently traffic congestion has become the research agenda for a growing community of researchers particularly in developed countries. Directly or indirectly it has a relationship with on-street parking management, road way characters or capacity, and can affect peoples in various ways: long travel time and high fuel consumption. Consequently, this chapter is focused on these elements and congestion relief strategies from different writers view of points.

## 2.1 Urban Traffic Flow Characteristics

Road transport dominates other mode of transports in our world. The most common urban road transport modes are public transport: public buses, taxis that either scheduled or non-scheduled or based on demand, individuals motorized passengers (automobiles) and freight transport (trucks), and non-motorized "*slow modes*" of transport, principally walking and cycling, sometimes animals: donkey and horse riding also (Winder and Morin, 2009, p. 14)

Non-motorized travel, such as walking and cycling movements has a positive impact for reducing automobile trips in most urban areas. However, in developing cities, infrastructures for non-motorized transport are inadequate and because of these passengers forced to use cars even for short trip (Litman, 2003). In addition, in developing cities, high traffic volume is occurred during peak period in which large number of traveling is concentrated because "*activities starts up in the early part of the day, so numerous journeys … take the same time. A similar pattern occurred in the afternoon when … business activities end*" (Ogundipe, 2007, p. 171) and the portion of trips made by single occupant (small size) vehicles by commuters (Litman, 2003)

## 2.2 Causes and Impact of Traffic Congestion in Urban Area

The most known causes of traffic congestion are recurrent and non-recurrent congestion.

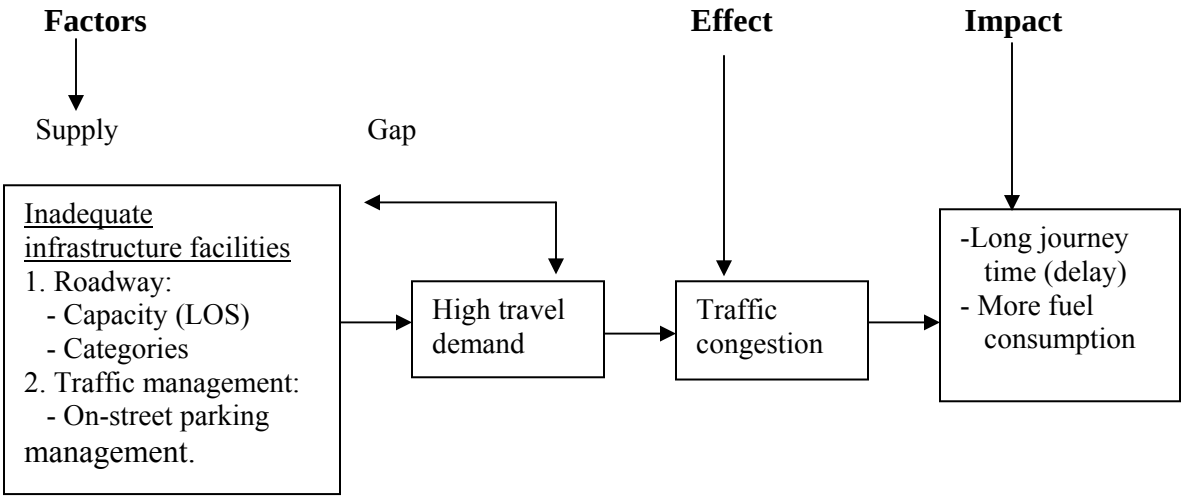
### 2.2.1 Recurrent congestion

Regularly occurred on the transportation system, such as daily commuting or weekend trips, traffic is vulnerable to sudden breakdowns as demand approaches the maximum throughput capacity on a link or in the network. *"Roads are operated near to their maximum capacity…. saturated intersections can quickly give rise to queues whose upstream propagation can swamp local roads and intersections"* (European Conference of Ministers of Transport, 2007, p.15)

### 2.2.2 Non-recurrent congestion

It occurred irregularly and unexpected, such as crashes, special events, snow, rain, fog and so on that affect parts of the road transportation system which is not easily predicted

Fig.2 Conceptual framework explaining congestion and its impact




Source: (Adopted from Loop, & Perdok, n.d.)

Many conceptual frameworks explain the causes and the impact of vehicle traffic congestion in different way. However, for the aim of this study, the above conceptual framework is adopted. In literatures, most writers argued that traffic congestion has an impact on travel time and fuel consumption, among them Ogundipe, (2007, p. 170) illustrates that "*traffic congestion can causes more fuel to be used*" European Conference of Ministers of Transport, (2007) supports Ogundipe's idea above.

Hours are lost or delayed due to various factors, among which the direct indicators are the imbalance between demand and supply: number of vehicles or traffic volume, like trucks, buses, private cars etc. exceeds the existing road capacity (Loop, & Perdok, n.d.). Moreover, the capacity of a road can be measured by comparing the traffic volume and travel time. However, traffic management, like on-street parking conditions can affect the performance of the roads (I bid).

## 2.3 Road Way Characteristics

In most countries, road transport has a great share than other modes in transporting goods and passengers; it is also confronts with serious issues, most notable is- traffic congestion which is a result of excessive utilization of the road infrastructures due to high number of pedestrians, small road network length, a high portion of the population engaged in informal business sector, and poor public transport supply are not based on peak hour demand which result in long travel journey period or delay (Langen and Tembele, 2001; Winder and Montin, 2009) are the few.

Congestion can be measured in various ways, including roadway level-of-service (LOS), and average congestion delay compared with free-flowing traffic (Litman, 2005). The capacity of a road depends on various design factors, such as lane widths and intersection configurations among others. As indicated in various literatures, it is possible to conclude that capacity of a given road can be determined by actual traffic volume or level-of-service of the roads (VTPI, 2009; Winder and Motin, 2009).

### 2.3.1 General road classifications

There are several basic road classifications in urban areas, they are basically based on:

1. Traffic: such as volume and type
2. Function: which express a road in its functional importance in the whole networks
3. Administrative: on the jurisdiction of individual administrations on various roads. For the purpose of this research, the first two classifications are discussed below.

#### 2.3.1.1 Traffic volume

As Langen and Tembele, (2001), and Orn (2002) stated, the capacity of a road depends on various factors, some of which are lane width and configurations of an intersection. Orn stated the traffic volume of road ways for different lane as follows.

Table 2.1 Maximum Traffic Volume (Passenger Cars per Hour)

| Type of way | LOS A | LOS B | LOS C | LOS D | LOS E | LOS F |
|---|---|---|---|---|---|---|
| 4-lane freeway | 700 | 1,100 | 1,550 | 1,850 | 2,000 | Unstable |
| 2-lane highway | 210 | 375 | 600 | 900 | 1,400 | Unstable |
| 4-lane highway | 720 | 1,200 | 1,650 | 1,940 | 2,200 | Unstable |

Source: (Orn, 2002: p. 12)

Table 2.1 shows the traffic volume per lane for different type of roadways. The traffic volume is increasing when one passes from "A" to "F" level-of-service for different lanes, road capacity is positively proportioned to the number of lanes (Zhang & Yang, 2005), and as traffic congestion is a non- linear function in its characteristics, a small change in a traffic volume can result in a proportional change traffic flow. For example, a 5% reduction in traffic volume on a congested highway may reduce delays by 10 – 30% even if the size of vehicles directly related with the road space (Orn, 2002).

Delay has a direct relationship with the volume of traffic. Level-of-service (LOS) indicates traffic volume on the road (Mathew and Krishna, 2007) and delay becoming more and more serious when go from "A" to "F" level-of-services. For example, except for F- level of service, which is so flexible or undetermined, delaines for "A" level- of-service is less than 15 seconds, and for "B" level-of-service is between 15 and 30 seconds and so on (Joel Marcuson, 2010). Similar to the idea of Mathew and Krishna (2007), Transportation Research Board of USA (2000) stated time delaines with in each level-of -service at different geometrical road designs as follows.

Table 2.2 Delay in each LOS for an intersections and Street/roads

| LOS | At signalized intersection (second/vehicle) | At un-signalized intersection (second/vehicle) | At Streets/roads (Using queue) | Remark |
|---|---|---|---|---|
| A | < 10 | <10 | <15 | There is high delaines at Streets than un-signalized & signalized intersections |
| B | 10 – 20 | 10-15 | 15-30 | |
| C | 20 – 35 | 15-25 | 30-55 | |
| D | 35 – 55 | 25-35 | 55-85 | |
| E | 55 - 80 | 35-50 | 85-120 | |
| F | > 80 | > 50 | Unstable | |

Source: (Adopted from Mathew and Krishna, 2007)

**Level-of-service A:** Individual vehicles flow freely, not affected by others.

**Level-of-service B:** though it is in a stable flow condition, obviously additional vehicles joining the traffic stream will affect traffic movement. However, there is a relatively freedom in speeds.

**Level-of-service C*:*** There is a relative stable flow, but individual vehicles influence the flow immediately and become significantly affected by interactions with other vehicles in the traffic stream.

**Level-of-service D:** It is a crowded roadway situation as mobility and a stable flow is restricting with a large number of vehicles. Speed and freedom to movement are harshly restricted.

**Level-of-service E:** Roadway accommodates nearly to its full capacity, low speed, and small increment in the traffic volume will affect the traffic movement more.

**Level-of-service F*:*** Vehicles move in a locked each other with in front and beyond condition. Speed is mostly to zero, and the travel time cannot be predicted.

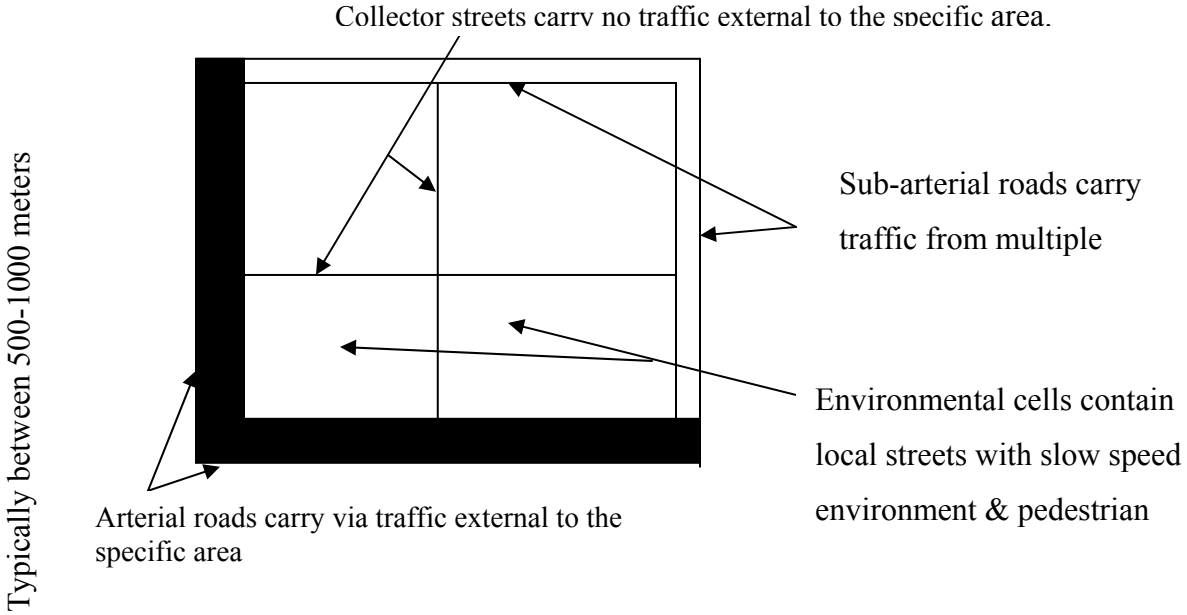
#### 2.3.1.2 Functional classification of road

Most authors argued that there are four main road types in urban area based on their functions. Eppell, Bunker & Mcclurg (2001), Langen & Tembele, (2001), and Malenkovska, Donceva & Bunevska (2009) have common arguments on road functional classification in urban areas. They are:

#### 2.3.1.2.1 Principal arterial roads

Arterials have high mobility level in connecting major trip generators, which demand long trip length and high traffic volumes, and speeds than on local and collector Streets. Urban principal arterial system are streets and highways significant to the correspondingly area, assigned to serve the major activities, highest traffic volume corridors and longest trip desires that provide access to various land uses, such as houses, shops, small business, and work shops. Except expressways, sidewalk is important on all streets, and particularly necessary on collector and arterial roads.

Fig. 3 Hierarchical of road in urban area




Source: (Eppel, Bunker and Mcclurg 2001: p.4)

#### 2.3.1.2.2 Minor/sub-arterial roads

Urban sub-arterial street system offer lower mobility level; put the accent on land access, and carry through traffic between multiple specific areas(collector streets) and the arterial roads.

#### 2.3.1.2.3 Urban collector streets

Urban collector street system has two significant features: land access service and connection of the urban areas. It links the local and arterial highways and serves subordinate traffic generators.

They bounded environmental cells within the specific urban area, which contain **local streets** with low speed environments and pedestrian priority.

#### 2.3.1.2.4 Urban local streets

The lowest level of mobility and the highest land access are the basic characteristics of the urban local streets that locate with in environmental cell or specific area, and serve a relatively minor role in the wider city context for carrying motorized traffic. Consequently, traffic volumes and speeds on these roads should be low.

## 2.4 Congestion Relief Strategies

Even if there is no single best approach to overcome congestion as it takes on many faces (caused by many different processes and occurs in many different contexts), demand management strategies also called mobility management can help in solving multiply problems and provide various benefits of the transport system, including congestion reduction, vehicle fuel efficiency, and parking improvement (Litman, 2009). However, from various interrelated strategies, there are some more effective strategies in overcoming traffic congestion. This may include along with the supply side that account for how residents and roadway users as well as their longer-term mobility preferences are fulfilled (David, Karen, and Rebecca, 2001).

### 2.4.1 Parking management

Parking Management, is activity of supply, price and regulation of parking facilities (VTPI, 2008), significantly affects travel behavior: if parking becomes more abundant and cheaper, will lead to increase automobile demand that result in large volume of vehicles. On other side, it can play a great role in solving congestion problem if it managed well. The provision of parking should not be too much as well as insufficient. Thus, parking policy and provision requirements are essential in reducing traffic congestion (Du Toit, et al, 2001). Moreover, Hitge and Roodt, (2006) state clearly as:

> *… the duration of car parking has a direct relation with the size of shopping center, economic activity of the center district, and policy, like parking cost. So that, from different alternative, factors like availability of suitable public transport, proximity of parking, and paid parking would lead to a reduction in parking demand*.

#### 2.4.1.1 Regulate Parking Use

Parking use should be regulated that aimed to use parking spaces and travel efficiently. Discount for residents parking and limit parking duration according to land-use type, and traffic volume, expected to increase the parking turnover rate and it favors shorter-term users or parking duration for deliveries and shopping. Regarding this, Victoria Transport Provision Institution, (2009) disscused the feature of good parking use that minimize congestion as follows:

> *limit on-street parking of large vehicles (e.g., vehicles over 22 feet long) that obstacle the traffic movement, prohibit on-street parking on certain routes (arterials roads), during rush hour so as to maintain the smooth traffic flow traffic, and special parking regulation to favor priority vehicles, like emergency, service, etc.*

Obviously, in reducing congestion, it is important to eliminate or minimize free parking in a specific place (Seattle Urban Mobility Plan, 2008; Environment Pollution (Prevention and Control) Authority, 2009). Variable-rates parking price has a great role in reducing parking demand when compared with free parking, like higher rates during peak periods and lower rated during off-peak periods on-street spaces is more effective in reducing peak use (Shoup, 2005 cited in VTPI, 2009*)*.

The empirical studies have supported the above concept. For instance, a case study by the Environment Pollution (Prevention and Control) Authority, (2009), carried in Japan shows a positive change after formulation and effective implementation of a new on-street parking regulation (high price with time variable-rates) since June, 2006 on major cities in Japan. Three months later, it is reported that nearly 74% and 73.3% decline in illegal on-street parking in Tokyo and Osaka respectively which reduced the traffic congestion level on main roads from 27% to 23% at 2 p.m to 4 p.m than the pervious time. The same to Japan, Weinberger, Kaehny and Rufo (2009) have stated that, in USA variable pricing policy on- street parking in peak hours also encouraged the short stays, high turnover rate and faster deliveries.

### 2.4.2 Flextime

To overcome congestion problem, most writers, such as David, Karen and Rebecca (2001), and Orn (2002) suggested that flextime work schedule is one mechanism that allow some different working time for daily work of people. For instance, it is better to have different work schedule of the day instead of starting all works at the same time (e.g., start work at the same time in morning and end in evening) that lead high unidirectional travel demand or making trip together.

### 2.4.3 Build and improve capacity of roads

To Hokao and Sulaiha (2009), and Texas Transportation Institute (2005), increasing the roads network coverage through construction and enhancing the capacity of the existing intersection will have a positive impact in mitigating traffic congestion. By improving their design: widening the road space of entrance and exit by shifting the reservations areas to the existing road, providing exclusive lanes for large size vehicles that able to turn, and move easily, and proper traffic signs of arterial roads.

### 2.4.4 Land-use planning measures

Land-use planning is another type of strategy that can influence congestion. In cities travel demand is increasing dramatically because of sub-urban expansion (William, 2008; John, 2009) People want to live at periphery in order to take the advantage of low land price and moved to the center of urban area for work. Thus, to influence the process, land use planning should be integrated with transportation planning strategies. These include land use controls (zoning), urban growth boundaries, and development policies (transit-oriented design, which provides land use densities and forms to favor transit use) and also taxation policy by providing incentives for high-density development so as to address transportation-related issues (Texas Transportation Institute, 2005; Hokao and Sulaiha, 2009)

These various and interrelated land-use management strategies can affect traffic movement of an urban area. For example, several studies indicate that **transit- oriented development** "*encourages dense development within walking distance (0.4 to 0.8 km) of transit stops*" (Litman, 2003; p. 13) can significantly reduce travel distance (Richard et al., 2003; Cervero, 2004; Gard 2007)

by gathering residential and commercial buildings near to a transit center can minimize personal car ownership. In addition, same token by Victoria Transport Policy Institute (2008) indicates that **improved access management** via arranging shops together can improve access.

### 2.4.5 Improved public transport

Public transportation is one and the most important means of alleviating traffic congestion for it makes roads work better by reducing the number of vehicles on the road. As Timothy and David (2005) indicated, without public transportations, the annual increase of travel time due to traffic congestion would have been reached to 1.1 billion hours globally. This show that, a great concern should go towards the expansion of high-capacity public transportation system, like introduction of light rail, heavy rail, rapid buss transit, and high occupancy vehicles (HOV) lanes, which coupled with better management of the existing road network and traffic management (Litman, 2008).

## 2.5 Research on Congestion Impacts and Mitigation Strategies: the case of three cities

### 1. Chicago- America

The actual economic impacts of traffic congestion can differ from one area to other area, depending on its economic profile and business location pattern. There have been prior attempts to estimate the economic impacts of congestion through business surveys, including most notably research in Chicago and Philadelphia by Weisbrod, Vary, and Treyz (2003) examined how various producers of economic goods and services are sensitive to congestion, through its impacts on business costs, productivity and output levels. As a result, it recognized different types of congestion costs, such as:

**Travel Cost**: Congestion has an impact on the travelers (the added time) as well as increase costs of vehicle operators (fuel and spare parts) are the key components of travel system inefficiency.

**Additional Business Operating Costs**: Traffic congestion can impose additional costs to businesses associated with freight and service deliveries. For instance, delays in delivering time-sensitive freight some cases can impose additional inventory and logistics

costs of receiving and distributing the products, as a result a great impact is fall on the end users.

Though this study did not layout congestion relief intervention in details, it highlights some strategies. Among others, business organizations should mix technology, like labor and capital input, reduce the size of delivery areas, change delivery scheduling or pricing policies, serve smaller or more specialized markets for workers, suppliers and customers. The production function model is also alternative strategy: a choice among inputs, including specialized labor and materials used in the production or provision of the products and services combined with inputs that best suits their needs and maximizes their profit.

**2. Hanoi-Vietnam**

An empirical study has been carried by Thuy (2003) in Hanoi- Vietnam that shows traffic congestion is a common problem in many roads of Hanoi due to different factors: economic development cause increasing number of private vehicles, especially motorcycles that leads to the demand of road construction and road expansion on the supply side. For this problem, as he mentioned, the government was constructed new roads that relieved congestion for some years (from 1995 – 1999). In the construction period, some road space had used for construction worksite, such as materials and equipment storage. Therefore, during construction time, traffic congestion along the road, especially at the intersections areas appeared more heavily and frequently due to the limitation of road space. On the other side, after the road is effected or open for traffic, the problem of traffic congestion was again revealed because of new land use development was built around it, such as development of residences, shops, industrial parks, markets that narrowed the road width and capacity, which in turn leads to a crowded traffic environments.

In order to narrow down traffic congestion problems for long run, the research suggested some intervention, such as:

(1) **Development of public transportation system:** It is the first priority, like mass and rapid transit- metro and light railway system.

(2) **On the supply side**: Capacity of transportation system in general and road network in specific is require to be expanded.

(3) **On the demand side**: Travel demand management is needed for reducing the potential increasing number of motorcycles and cars (15% - 20% increasing per year).
For example, high import tax on personal automobiles, vehicle owner and registration fees, different prices of petrol for public and private vehicle, policy allows every family has one vehicle only. In addition, high parking fee, parking prohibition, and time staggering of offices should be implemented.

(4) **An integrated land-use and transport planning:** For urban transportation sustainable development, it is suggested that government should formulate and implement responsive policies that supported by whole community participation for its effective implementation.

**3. Lagos- Nigeria**

A case study by Joshua, et al., (2009), examines the causes, effects and possible measures of road traffic congestion in some selected areas of Lagos State. According to this study, there are many factors contributing to the traffic chaos in Lagos State, mostly:

**a) Social and economic factors**: Land-use of Lagos is poor, like most offices are concentration at its Island that affects the travel direction- one or the same direction during the peak hours, and also inadequate public transport system are the main factors.

**b) Road factors (including design and control)***:* From many factors, he stated that the most obvious cause of traffic congestion in Lagos is the condition of the roads and other interrelated elements. Most roads, are highly crowded, particularly the feeder, as a result, traffic increases up that build queue from these feeders that uses for exits and entrance to the main roads. This is because roads are too narrow and lack of sidewalks that hinders the free movements of vehicles particularly when another vehicle passes from the opposite direction, and pedestrian sharing traffic lanes. The situation is aggravated by unregulated on-street parking on the already too narrow streets.

**c) Vehicle factors**: Even if it expected that the standard of vehicles to fit the geometric standards stated by law, most motor vehicles' length, width and height are not fit with road standards.

**d) Accident factors**: Irresponsive traffic management in removing disable vehicles immediately and of lack immediate settlement by the parties in the case of more serious accident cause queues in both directions of traffic.

Therefore, the study concluded that poor road condition, accident, absence of integrated transport system, and inadequate traffic planning were the major causes of traffic congestion in Lagos State. Lastly, based on its findings, the study suggested some mitigation strategies for congestion, like- enhanced transport coordination, road capacity expansion (junction improvement and separate lanes for specific user groups- public buses and emergency), and demand management (parking restriction, park and ride, congestion pricing, and incentives to use public transport).

# CHAPTER THREE: METHODOLOGY

## 3.0 Introduction

Obviously, it is impossible to examine all elements of a given target population owing to high cost, time, and inconvenience of a large data administration. However, it is possible to investigate and generalize to the given population by selecting representative sample elements. As a result, a sampling technique of the study chosen based on the aim on hand, and other related sub-titles are going to be presented in this chapter as follows.

## 3.1 Operational Definition of Variables

### 3.1.1 Vehicle traffic flow characteristics

There are variables that can assess the motorized traffic flow conditions that have many characteristics, such as:

**Trip purpose:** is for job, shopping, education, recreation or other purpose

**Trip hour**: in which time most traveling or journey is made.

**Traffic compositions**: The compositions or type of vehicles traffic passes along the road.

**Vehicles physical conditions:** life span or vehicles service have a relationship with their technical and physical condition.

**Passengers' daily trip direction:** to which direction mostly movement is taking place.

### 3.1.2 Causes of vehicle congestion

Most authors agreed that there are two main types of traffic congestion: it can be *recurrent:* when it occurs regularly or daily base, making it easier to manage and *non-recurrent* which occur due to accidents, special events or road closures (Texas Transportation Institute, 2005; VTPI, 2009)

There are variables that can measure the main causes of vehicle traffic congestion. Like, imbalance between the vehicles volume and road capacity (LOS), illegal on-street parking (double parking, and park for long time specially during peak hours), inflexible work schedule that start and end at the same time, poor vehicle condition (too old and technical inefficient), traffic accident, and un-integrated land use.

### 3.1.3 On-street parking management

There are many factors or variable that influences the road capacity, such as on-street parking. The supply, price and regulation of on-street parking should aim to enhance the smooth traffic flow of a given area. As a result, it should supply sufficient space, variable price rate and duration, and prohibition of parking on specific place during peak hours.

### 3.1.4 Road capacity

The extent of traffic congestion is differing from one level-of-service to other level-of-service. Road become more congested and incapable if the volume of vehicles increases from “A” level- of- service to “F” level- of- service.

### 3.1.5 Congestion impact on travel time and fuel consumption

The simple method in measuring the variables of the impact of traffic congestion is how many litters lost due to congestion. Average vehicle’s fuel consumption that is the difference between kilometers running per litter at a normal daytime and a congested traffic flow condition (low speed) along with amount of fuel consumption with in these environments. Average delay per vehicle and per passenger can be also measured via using queue length. For instance, estimated number of vehicles and passengers stopped in and leaved the queue with in a specific time interval are the main variables that able to measure delaines.

## 3.2 Research Design

Among different research design, both qualitative and quantitative descriptive research design used for the purpose of this study which enable the research to interpret the finding adequately and accurately. Consequently, this paper qualitatively described the existing vehicle traffic flow, road characteristics, and on-street parking condition. In addition, describing the relationship of vehicles kilometers running per litter with in a normal and congested traffic conditions, amount of fuel consumption, and its impact on travel time (delay) using queue measurement along the road from Total to Ayer Tena quantitatively.

### 3.3 Sampling Technique

Because of its nature and goal of the study to be attained, the research applied both probability and non-probability sampling technique. Thus, probability sampling technique (cluster) used in determining the case study area in the city. So that, the city classified in to 10 different geographical areas based on the existing sub-city administration boundaries. Because the preliminary information from Transport Branch Office of Addis Ababa shows it is one of the twenty areas of the city that has high traffic volume, the study selects the road from Total to Ayer Tena in Kolfe sub-city purposively. The street is open for all vehicles of the city, thus, total population of the study considered all registered motor vehicles of the city, though the case study is on Kolfe sub-city.

Before identifying the sample frame, an observation made to estimate the total volume of passengers that travel along the road per hour. Thus, the carrying capacity of different modes of motor vehicles is assessed in the two travel times, morning and evening. As a result, the buses are almost using their full capacities in the morning hour and 50% to 75% to their capacities in evening hour, where as the private vehicles carrying 25% of their capacities in the two-travel times. Thus, the researcher decided to allocate according to what have been observed. Spot count indicated that, on average **1,295** vehicles are passing along the street per hour in both directions with estimated carrying total passengers of **11,669** on average (see appendix-4).

To achieve a stated objective with resource on hand, the research has adequate sample size depending on the size of the sample frame mentioned above. As the sample frame (passengers) is greater than 10,000 per day, the sample size is determined as follows.

$$n = \frac{z^2 * p*q}{d^2}$$

**Where**

**z** = is the standard normal variable at required level of confidence

**p =** is the proportion in the target population to have characteristics being measured

**q** =1-p: is the opposite of "p" above and **d** = is the sample error

There for:-

Level of confidence is 90% (z-value is 1.645).

p = 0.5

q = 1- 0.5 = 0.5

d = 5%

### 3.3.1 Rationale for sampling technique used

1. In providing true information, peoples may need some knowledge or experience on traffic congestion
2. The population size is large and contains different groups.

Because of these two reasons, the sample size increased by minimizing the sample error to 5%, and it is 90% certainly that sample respondents gave true information on the population parameters and 10% out of the true answer (Kothari, 2004; free encyclopedia; http://www.mailund.dk/index)

Therefore, $n = \frac{(1.645)^2 (0.5) (0.5)}{(0.05)^2} = \mathbf{270}$ individuals respondents.

The validity or relevance of the data was assured through applying purposive non-probability sampling technique in determining the sampling unit of the study. So that, three group of the society who make at least two trips per day along the street - all passengers: government and private employees, business persons, all motorized vehicles drivers, and traffic polices are selected. From them, 270 representative sample elements were randomly drawn, that is, 108 (40%) from all employees: government and non-government employees, 68 (25%) from business men and others, 89 (33%), from different motor vehicle drivers, and the remaining 5 (2%) from traffic police.

## 3.4 Data Collection Method

Relevant secondary data collected from different relevant bodies, such as Addis Ababa City Transport Branch Office, and Road Authority so as to assess the road network and on-street parking management. The primary data also collected by distributing structured

open ended questionnaires, and structured interview to the respondents at the case study area. Together with other assistance, a non-participant field observation survey also made, so that all motor vehicle volume is counted with their carried unit, queue length measured in order to know the average delay per vehicle and person along the road.

### 3.5 Data Sources

Secondary and primary sources data was collected from different sources, which is important in attaining the aim of the research. The secondary sources were from various books- journals, research, internet, and organizations' documents or report, such as data on road characteristics from Addis Ababa road authority and data on parking condition along the street from Addis Ababa Transport Office. This helps to assess the existing road and parking condition. Where as the primary source were collected from open and closed structured questionnaires to passengers, motor vehicle drivers (aimed to assess impact on vehicles' fuel consumption), and structured interview for traffic policy which used to identify the characteristics and causes of vehicle traffic congestion, and the current road and parking condition. In assessing or measuring the impact of vehicle congestion on travel time or delay of per vehicle and person, primary data was also collected through on-street survey. Queue length measured at starts of counting process: recording all stopped different types of vehicles by looking at the end of queue and all leaving vehicles at the front of the queue simultaneously with in each interval (each interval has 2 minutes), for maximum 30 minutes and 15 intervals at each intersection.

In addition, to minimize the effect of uncontrolled or extraneous variables on dependent variables, they managed in two ways. First, keeping them as *constant*, for instance, drivers' skill and discipline, traffic signals, traffic rule enforcement, societal traveling cultures, and the topography of the city while others included as *independent variables*: like the physical condition of vehicles and traffic accident along the road.

## 3.6 Results and Discussions

Among different data analysis methods, this study used percentage, average, regression, correlation, and other technique in order to examine and assess the relationship and influences of variables to address the research questions of the study, and the finding presented via different charts, tables, and text. For instance, as the case study area or road has intersections from its starting and ending, this study analyzed the average delay per vehicle and person by using queue length at each intersection.

### 3.6.1 Delay analysis on road using queue length

Queuing delay at the intersection occurs when vehicles are waiting in each link of the intersection to enter the traffic circle, and the queue forms back of the circle on the road that occur due to traffic flow on opposite direction. Formula from Langen and Tembele, (2001) has adapted to measure delay using queue length.

#### 3.6.1.1 Steps in measuring travel time delay

**I. <u>Standards</u>**

- 2 minutes observation time interval for each queue
- Maximum 30 minutes and 15 counting intervals for all counting process per day
- The total field observation has 3 days (1.5 hours) on three sections.

***Section-1***: from Total intersection to Zenbwork intersection (half an hour of observation: 7:30 – 8:00 a.m.)

***Section-2***: from Zenbwork to Ayertena (30 minutes observation: 5:00 – 5:30 p.m.)

***Section-3***: from Ayer Tena to Zenbwork (30 minutes observation: 7:00 – 7:30 a.m.)

**II. Steps**

- Before measuring queue length, road had marked on its side (edge) to simplify the process.
- Record all stopped vehicles by looking at the end of the queue and all leaved vehicles front of the queue; and queue length at the end of the time interval (2 minutes) simultaneously.

- Number of vehicles stopped = $\sum Sv$
- Number of vehicles leaved = $\sum Lv$
- Number of vehicles with in each queue = $\sum Tvqi$
- Number of vehicles that passed on opposite direction = $\sum Vp$
- Number of passengers that passed on opposite direction = $\sum Pps$
- Number of passengers with in each queue = $\sum Pqli$
- Calculating total time delay of all vehicles (TDv)

  $$TDv = (\sum Tvqi)\ (Ti)$$

- Calculating average time delay per vehicle (Adv)

  $$Adv = \frac{Tdv}{\sum Vp}$$

- Calculating total time delay of all passengers (Tdps)

  $$Tdps = (\sum Pqli)\ (Ti)$$

- Calculating average time delay per person/ passenger

  $$Adp = \frac{Tdps}{\sum Pps}$$

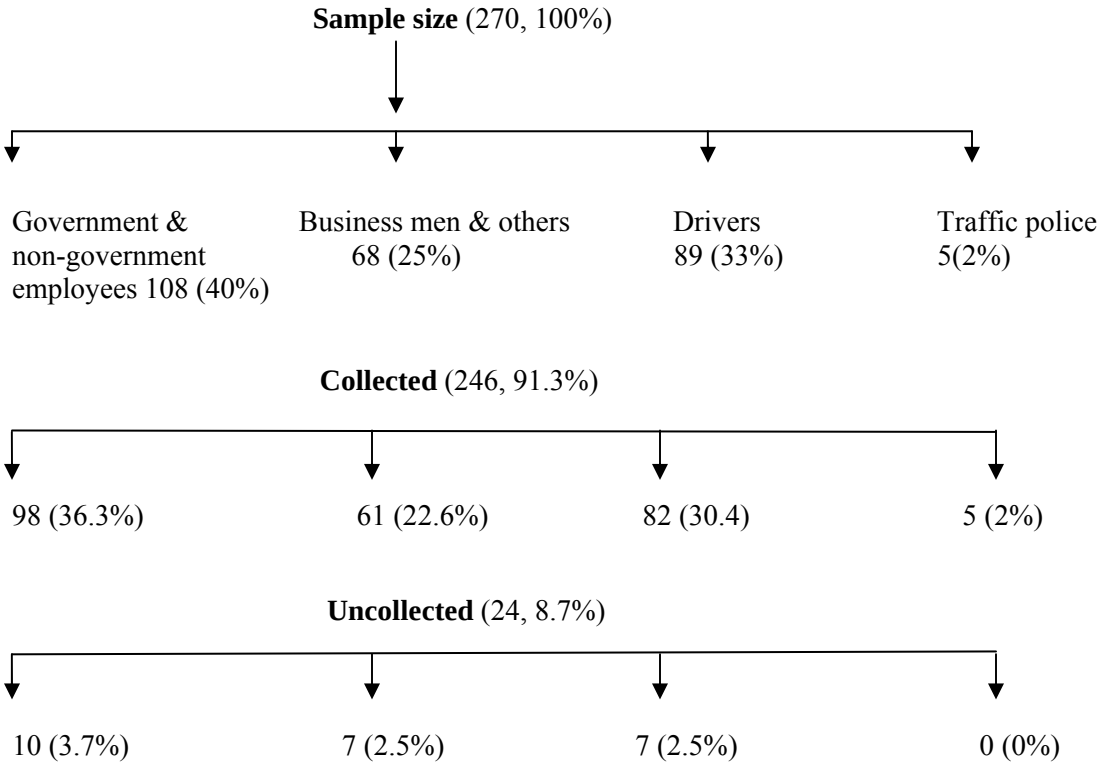
# CHAPTER FOUR

# RESULTS AND DISCUSSIONS

## 4.0 Introduction

Different types of data were collected which is relevant in assessing the current traffic flow status of the city: its impact on fuel consumption and on-time service delivery. For simplicity, results are presented and discussed through various statistical tools simultaneously in respect to the research objective on hand.

## 4.1 Response Rate




From a total of 270 questionnaire distributed to respondents, 246 (91.3%) is collected where as 24 (8.7%) of the total is un-collected.

## 4.2 Demographic Data

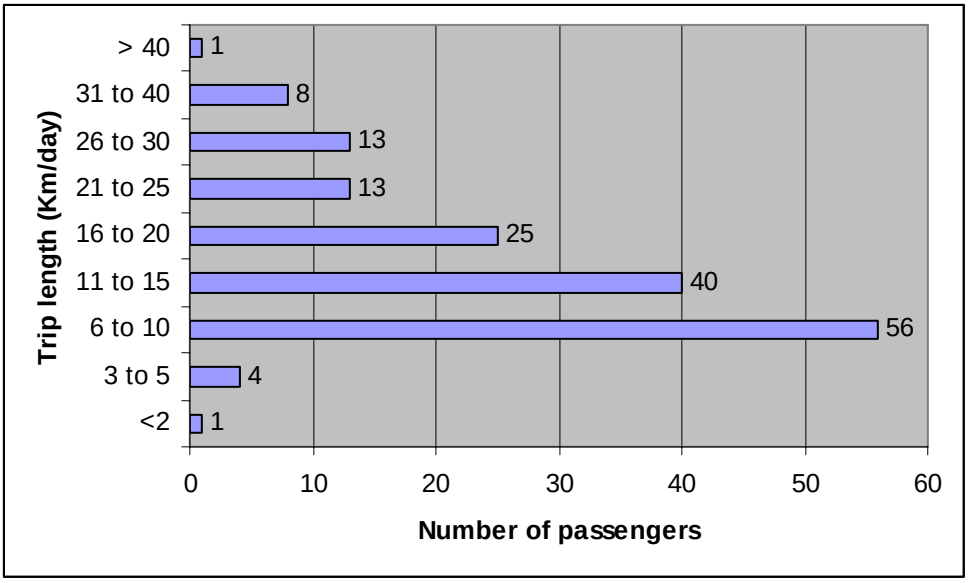
The respondents of this study are composed from three individual groups of the society who use the road for different purposes. Government and private employees, self-employed or business persons, drivers of various motors vehicles, and traffic police who manage the traffic on the road. From the 246 respondents, 98(39.8%) are government and private employees, 61 (24.8%) are business persons group, 5 (2%) are from traffic polices who gave adequate information on traffic congestion on the road. From 82 of vehicles' drivers, 36(44%) are private cars, 22 (26.8 %) are taxis, 16 (19.5 %) are buses, and 8 (9.7%) are trucks.

## 4.3 Results and Discussions

### 4.3.1 Traffic flow characteristics and cause of congestion along the road

#### 4.3.1.1 Passenger average trip distance

Fig.4 Trip length (Km/Passenger/day)



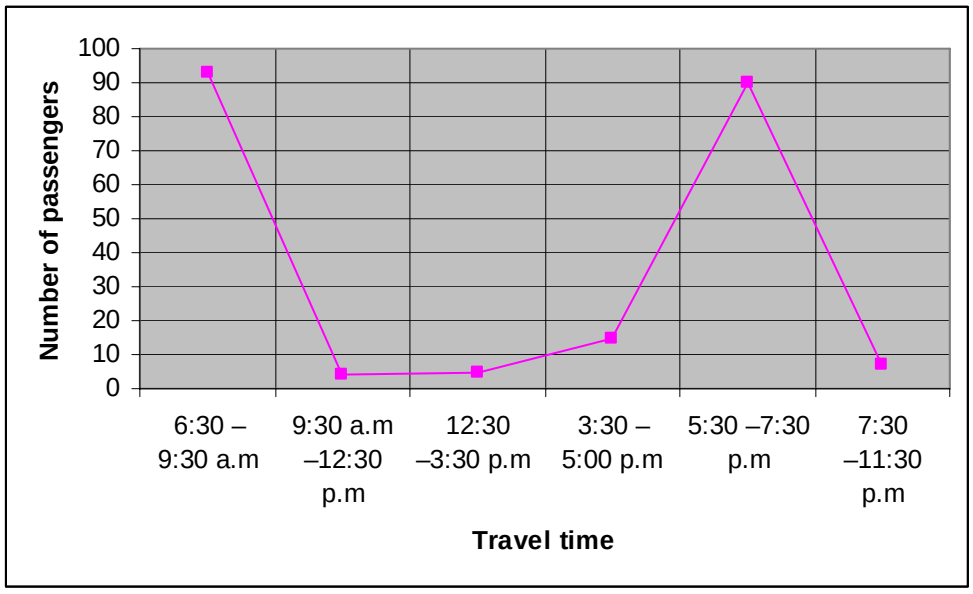

Source: (Sample survey, 2010)

It is obvious that trip length has a direct relationship with land-use patterns and congestion. For example, if trip length is becoming long, it needs efficient and responsive transport system that is capable to serve when and where it needed; otherwise, leads to traffic congestion problem. From sample survey (see appendix-5, no. 9) most passengers, 238 (98.7%) also have the same perception to the above idea.

Figure-4 above indicated that on average interval, the trip length km/passenger/day a long the road is from 6 –10 km as 56 (35.2%) of respondents state that they make their daily journey with in this length. So, it seems high (even some people are traveling beyond 10 km, i.e. up to 15 km, see figure- 4 above) that demands a good transport service for the public day to day activity. 140 (58%) of respondents also agreed that the traffic condition along the road is congested, and it is true from what has been observed during field survey.

#### 4.3.1.2 Travel hour along the road

Fig.5 Mobility hours of passengers on the route




Source: (Sample survey, 2010)

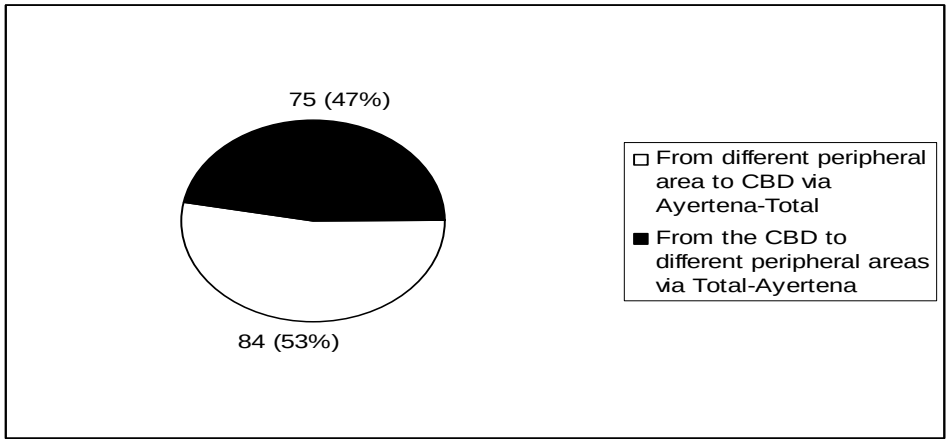
Travel time or hour is one and major important factor in assessing traffic congestion on a route or the road. Figure-5 shows peak and off-peak demand period on the sampled road. According to the survey made, two clear peaks hour volume has been observed.

1. **Morning peak**: The morning peak reaches its highest volume between 6:30 to 9:30 a.m.
2. **Evening peak**: The evening peak normally starts to build up between 3:30 to 5:00 p.m. and reaches highest density between 5:30 to 7:30 p.m. with a nearly vertical drop between 9:30 a.m. to 3:30 p.m. and 7:30 p.m. to 6:30 a.m.

This high travel need of passengers with in a specific period is the outcome of fixed work schedule that generate uni-directional traveling during the morning and evening peaks hour along the road which in turn leads to traffic congestion (see figure below)

**4.3.1.3 Passengers daily trip direction**

Fig.6 Travel direction between CBD & peripheral areas



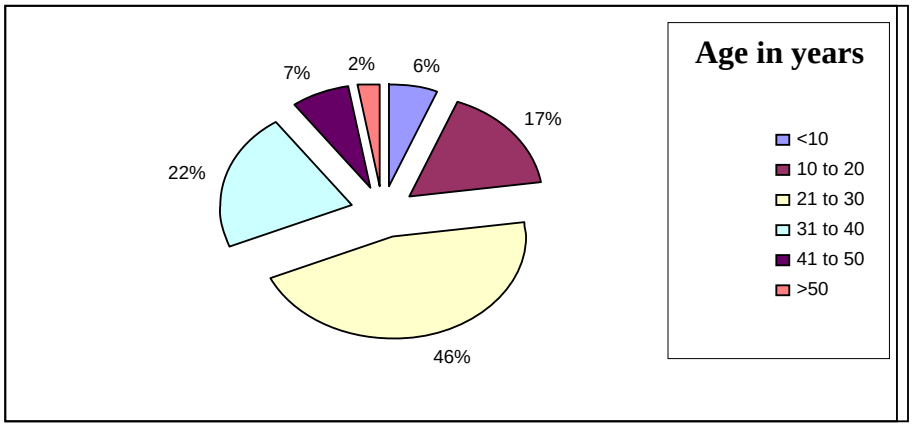

Source: (Sample survey, 2010)

In considering or estimating the traveling direction of passengers between central business district and different peripheral areas of the city through Total station to Ayer Tena and vice-versa, most respondents 84 (53%) are from various fringes part of the city to the center via their common route: Ayer Tena - Total, for different purposes. Like for work 94(59.1%), for market 31(19.5%), for education 25(15.7%), and the other 5.7% is for recreation and other social interactions.

This result indicates most peoples are working in central areas and reside around the nearby sub-urban of the city for various economic or social reasons or the mix of both.

#### 4.3.1.3 Vehicles physical conditions

Fig.7 Vehicles distribution in age

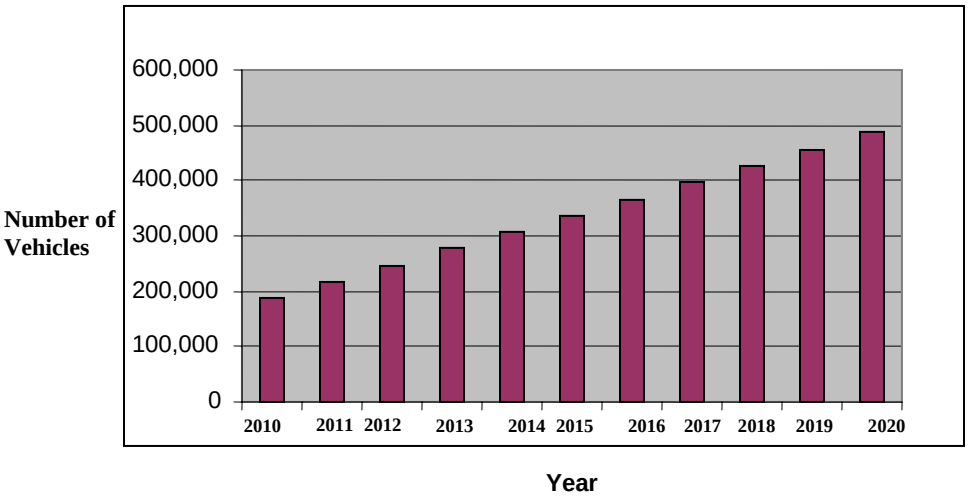



Source: (Sample survey, 2010)

Vehicles physical condition has its own influence on traffic flow of the city. In Addis Ababa, most cars are so old (46%, are between the age of 21 & 30 years) which are technically unfit, as 105 (43.5%) of respondents (see table-4.2 below) are also argued poor vehicle condition is the 5th factor for congestion which create physical traffic accident that exposes to congestion. If this trend is continued, (low turnover of stock) which coupled by additional 29,879.5 (1.6%) vehicles stock in each year in to the existing traffic, an imbalance between vehicles population and transport supply or infrastructures will be intensified.

#### 4.3.1.4 Future vehicles population growth

Fig.8 Forecasted Vehicles Population growth in Addis Ababa (2010 –2020)




Source: (Addis Ababa Transport Branch Organizations, 2010)

Table 4.1Vehicles Classification in respect to their carrying capacity

| **Vehicle Category** | **Vehicles carrying capacity** | | | | | | **Total** |
|---|---|---|---|---|---|---|---|
| | < 6 | 6-12 | 13-29 | 30-44 | >44 | Unknown | |
| **Public transport** (in seats) | 89158 (53.80%) | 25060 (15.12%) | 3357 (2.02%) | 595 (0.36%) | 1289 (0.80%) | 9 (0.005%) | 119,468 (72.10%) |
| | <16 | 16-36 | 37-70 | 71-120 | >120 | Unknown | |
| **Trucks** (in quintals) | 11082 (6.69%) | 15302 (9.23%) | 4333 (2.61%) | 5114 (3.61%) | 10360 (6.25%) | 73 (0.04%) | 46,264 (27.90%) |
| **Grand total** | | | | | | | 165,732 (100%) |

Source: (Addis Ababa Transport Branch Organizations, 2010, p.2)

It is believed that mass transport play a great role in urban transportation system. In Addis Ababa the number of large public transport is insignificant (see table-4.1). As the data is able to identify buses that have 30 and above seats are only 1434 (1.2 %), from a total of 119,468 (72.1%) public transport. The reaming 104,893 (87.8%) are small size vehicular with low carrying capacity. Such condition leads to high volume of traffic flow on the roads thereby traffic congestion will occurred. Moreover, it is predicted that for the coming ten years (2020) the volume of vehicles population will increase to 486,278 (159.4%) and 29,879.5 (1.6%) added in each year, and the current number will be doubled with in 6.3 years from now most of which are private and small personal vehicles (81.6%). During field survey, it has been observed that most vehicles have low carrying capacity; a result of an interview with traffic polices also show in a similar way.

#### 4.3.1.5 Causes of traffic congestion

Table 4.2 Factors for traffic congestion on Total – Ayer Tena road.

| No. | Variables | Rank | | | | | | | | | Total (100 %) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1st | 2nd | 3rd | 4th | 5th | 6th | 7th | 8th | 9th | |
| 1 | Imbalance between the vehicles volume and road capacity | 130 | 51 | 40 | 11 | 2 | 0 | 4 | 3 | 0 | 241 |
| 2 | Illegal on-street vehicle parking, boarding & alighting | 5 | 1 | 5 | 12 | 47 | 35 | 95 | 34 | 7 | 241 |
| 3 | Inflexible work schedule of people | 75 | 120 | 23 | 9 | 2 | 4 | 2 | 2 | 4 | 241 |
| 4 | Un-integrated land use | 19 | 35 | 50 | 110 | 12 | 5 | 5 | 4 | 1 | 241 |
| 5 | Unavailability of mass transit | 30 | 30 | 114 | 47 | 6 | 4 | 6 | 1 | 3 | 241 |
| 6 | Traffic accident | 0 | 3 | 5 | 3 | 33 | 42 | 51 | 91 | 13 | 241 |
| 7 | Poor vehicle condition | 3 | 1 | 8 | 8 | 105 | 48 | 45 | 19 | 4 | 241 |
| 8 | lack of transparent & good parking service delivery system | 0 | 1 | 3 | 12 | 13 | 100 | 30 | 70 | 12 | 241 |
| 9 | Informal on-street trade | 0 | 3 | 1 | 3 | 9 | 23 | 30 | 39 | 133 | 241 |

Source: (Sample survey, 2010)

Table 4.2 illustrates the distribution of variables in each rank that cause congestion as viewed by the respondents. For example, for the first rank, among 241 respondents, nearly 130 (54%) argue that the current vehicles volume exceeds road capacity and it is major factor for congestion problem. Inflexible work schedule is suggested to be the second factor, 120 (50%) which followed by inadequacy of public transport, 114 (47.3%), and the fourth cause is un-integrated urban land-use planning of the city, 110 (45.6 %). Moreover, 55.2% of respondents say that an informal on-street parking is not a great factor for congestion on this road. In addition, traffic polices, 5(2%), also agreed that high traffic volume is a major factor for congestion which occurred on a regular base (recurrent type of congestion).

## 4.4 Road Network Characteristics

Table 4.3 Trends of road network coverage of Addis Ababa (2006 – 2010)

| No. | Road hierarchy | Year | | | | | |
|---|---|---|---|---|---|---|---|
| | | 2006 | 2007 | 2008 | 2009 | 2010 | Average growth (%) |
| 1 | Arterial | 352 | 477 | 512 | 652 | Ni | 19.8 |
| 2 | Sub-arterial | 139 | 145 | 151 | 211 | Ni | 6.4 |
| 3 | Collector | 182 | 187 | 193 | 209 | Ni | 7.6 |
| 4 | Local | 177 | 181 | 193 | 208 | Ni | 7.5 |
| 5 | Gravel | 1400 | 1453 | 1488 | 1534 | 1637 | 58.7 |
| **Total** | | 2250 | 2443 | 2537 | 2814 | 3192 | **100** |

Source: (AACRA, 2010, p. 4-7)

As data from Addis Ababa City Road Authority, shows that in 2006 the road network coverage of Addis Ababa is 2,250 km which is 7.6% of all build up area of the city (169.02 $km^2$), however, after 3 years, in 2009, the coverage increased by 371 km (15.2%) or to 2814 km (that is 10.34% of all build area) of which 1534 (54.5%) is gravel and 652 (23.2%) arterial roads. Moreover, though there is no detailed information on road coverage, at the beginning of the current year (2010) road audit has showed that the coverage increased to 3,192 km. From this, gravel road take the highest proportion 1,637 (51.3%).

In summary, from 2006 to 2009, the total road length was increased by 25.1% (564Km) of which 54.5% is gravel and 23.2% is arterial.

From this analysis, it is important to see the road expansion trends against the future vehicles growth trend. Comparing to other hierarchical categories, relatively arterial road has more capacity in accommodating traffic than others; for example, it can serve over 20,000 traffic volume per day. Thus, it has great role in maintaining traffic flow of an urban area. When we come to the situation of Addis Ababa city, though it is increasing from year to year, from all road network coverage of the city, the proportion of arterial road is only 652km (23.2%) by 7metres width in 2009, and even this number will decline if it converted to different standard width. In contrary, vehicles population is growing up by 1.6% (29,879.5) each year which need additional road space for their daily mobility.

Note that the kilometers (km) given above has been converted from different widths to 7 meters width.

## 4.5 On-street Parking Management Condition of the City

### 4.5.1 Parking regulatory system

In parking management, trade-off between parking space demand and supply is one factor for healthy traffic flow of an area. In regarding this, Addis Ababa transport office is taking survey in identifying new area or space of parking demand and handing over to legible private sector on contract base. In its regulation, it is not allowed to misuse parking space for other purposes.

In managing parking condition of the city, traffic signs related to parking are assigned on both side of the road. For example, parking is not allowed on principal arterial roads or high ways like Total – Ayer Tena road, and areas that used for boarding and alighting of public transport: buses and taxis. Moreover, some factors affect parking supply or space provision- such as new development or constructions along the roadsides and road maintenance. Nevertheless, there is no clear policy and efficient mechanism that handle those temporary problems immediately even if it is now on planning.

It has found that on-street parking is not a major cause of traffic congestion along Total – Ayer Tena Street. Even so, it is should not be forgotten that on-street parking will be a major cause in the near future on this route as evidence shows vehicles population is highly increasing. Particularly code 2 and 3 (personal and private) vehicles will constitute 81.6% of all vehicles population growth in the coming ten years (2020), which obviously increase parking demand.

### 4.5.2 Parking price

With the exception for boarding and alighting of public transport areas, vehicles parking charge is directly related to their size and duration of stay instead of traffic volume of a given area. Parking is supplied from 7:00 a.m. – 7:00 p.m. of the day except Sunday and other national holidays.

Parking charge varies from birr 0.6 to 9.2 which based on vehicles size and parking duration as stated bellow.

Table 4.4 Parking price system of Addis Ababa

| No. | Vehicle size | Parking duration (in minute) | Price (in birr) |
|---|---|---|---|
| 1 | Small private automobiles | From 1 – 30 | 0.6 |
| | | From 31 - 60 | 1.15 |
| 2 | Medium trucks (up to 7 tone) | From 1 – 30 | 1.15 |
| | | From 31 - 60 | 2..30 |
| 3 | Large trucks (>7 tone) | From 1 – 30 | 2.3 |
| | | From 31 - 60 | 4.6 |
| 4 | Longer vehicle | From 1 – 30 | 4.6 |
| | | From 31 - 60 | 9.2 |

Source: (Addis Ababa transport east branch office, 2008, p.7)

## 4.6 Impact of Vehicle Congestion on Travel Time and Fuel Consumption

### 4.6.1 Delay measurement using queue length: delay per vehicle & passenger

**A. Survey area-I At Total intersection**

**Given**

Number of vehicles stopped = ∑Sv =180 vehicles

Number of vehicles leaved =∑Lv = 72 vehicles

Number of vehicles with in each queue =∑Tvqi = 99

Number of vehicles that passed on the opposite side ∑Vp = 57

Time interval of each queue Ti = 2 minutes.

**Computation**

1. Total delay of all vehicles (Tdv) = 99 * 2 minutes = 198 minutes

2. Average time delay per vehicle per direction (Adv) = 198/57 = **3.47 minutes**

3. Average delay per person per direction:

3.1 Total time delay of all passengers (Tdps)

Tdps = (∑Pqli) (Ti) = 1088 * 2 minutes = 2176 minutes.

3.2 Average time delay per passenger per direction

Adp = Tdps/∑Pps = 2176 minutes/479 = **4.54 minutes.**

**B. Survey area-II At Zenbwork intersection**

1. Calculating total delay of all vehicles (Tdv) = 55 * 2 minutes = 110 minutes

2. Average time delay per vehicle (Adv) = 110/43 = 2.56 minutes.

3. Average delay per person per direction:

3.1. Total time delay of all passengers (Tdps)

Tdps = (∑Pqli) (Ti) = 668 * 2 minutes = 1336 minutes.

3.2 Average time delay per passenger

Adp = Tdps/∑Pps = 1336 minutes/296 = **4.51 minutes**

**C. Survey section-III At Ayertena intersection**

1. Total delay of all vehicles (Tdv) = 82 * 2 minutes = 164 minutes

2. Average time delay per vehicle per direction (Adv) = 164/54 = **3.04 minutes**

3. Average delays per person per direction:

3.1 Total time delay of all passengers (Tdps) = 1330 * 2 minutes = 2660 minutes.

3.2 Average time delay per passenger per direction:

Adp = Tdps / ∑Pps = 2660 minutes/607 = **4.4 minutes.**

Table 4.5 Summary of delay on three intersections (Total-Ayer Tena)

| Name of an intersection | Average delay /vehicles/direction/ (in minutes) | Average delay/ passenger/direction (in minutes) |
|---|---|---|
| Total | 3.47 | 4.54 |
| Zenbwork | 2.56 | 4.51 |
| Ayer Tena | 3.04 | 4.4 |
| Average delay | **3.02** | **4.48** |

Source: (Field survey, 2010)

From the three intersections measurements, average delay per vehicle and passenger is high at Total intersection (i.e. 3.47 and 4.54 minutes respectively).

However, the average delay per vehicle and passenger throughout the road is almost 3 and nearly 5 minutes respectively.

### 4.6.2 Correlation and Regression Result of (km/litter) Traveling in Two Traffic Conditions

| | |
|---|---|
| Slope (b)/co-efficient: 0.92 | - |
| Y-Intercept (a)/constant: -0.932 | - |
| Regression equation (y): -0.932 + 0.92x | - |
| r | 0.97 |
| Mean(x) | 8.3 |
| Variance (x) | 4.6 |
| Mean(y) | 6.7 |
| Variance (y) | 4 |

Source: (Sample survey, 2010)

**Where:**

(x): Is kilometers traveled per litter in a normal traffic condition

(y): Is kilometers traveled per litter in a congested traffic condition

Fig. 9 Correlation of (x) and (y) values

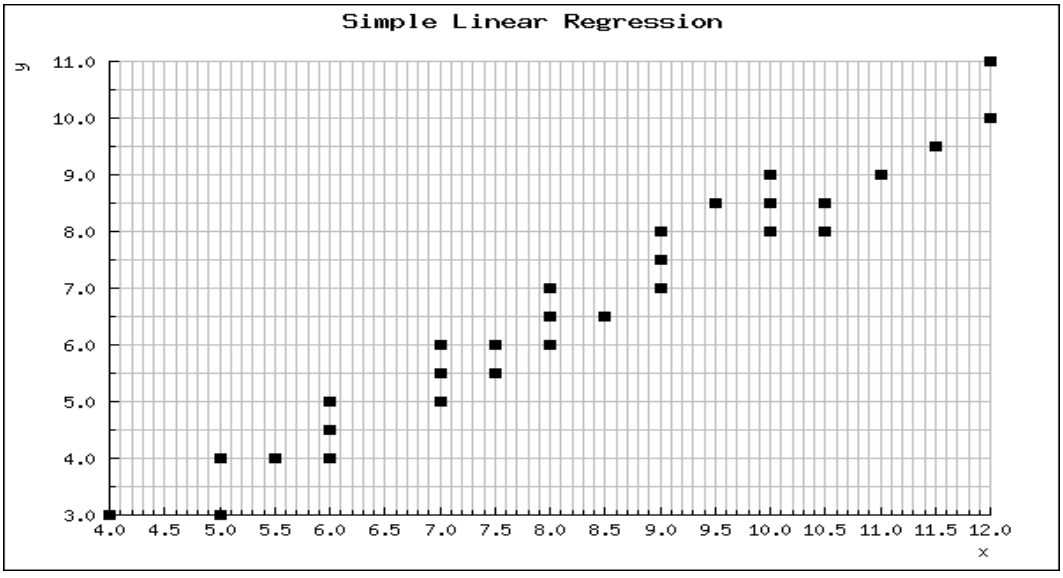
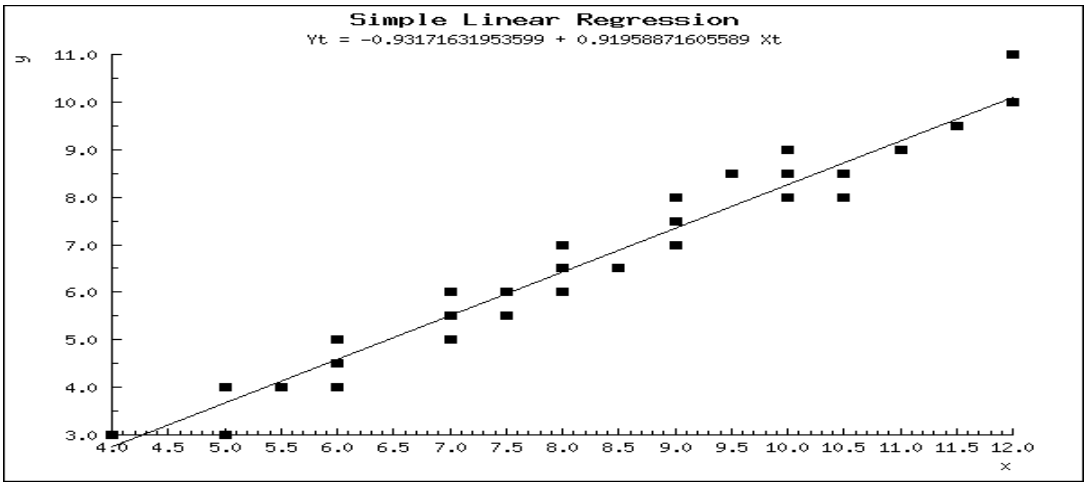


Fig. 10 Regression




The amount of distance traveling (km/L) by vehicles per litter of fuel is directly related to a traffic environment in which they interact. In a smooth traffic flow, they can run more km/L than in a congested condition (low speed) though it depends on their fuel consumption efficiency. The impact of congestion on vehicles daily fuel consumption can be measured indirectly through assessing the distance they are traveling with in two traffic conditions: via contrasting vehicles' distance traveling (km/L) in a normal time with a crowded traffic condition (that is, impact of congestion on km/L distance is depending on km/L distance traveled in a regular time).

The correlation of total 82 respondents regarding the distance traveling (km/L) is 0.97 which indicate the existence of very strong association between vehicles distances traveling per litter in a regular (free speed) and crowded traffic conditions, that is, most of them have same number of km/L in theses traffic environment. However, it is an inversely related to each other (between the two traffic environments), vehicles are moving less kilometers (as low speed) per litter than in a free traffic flow condition. In addition, it is possible to computed or predict the "y" values (km/L traveling during congestion along with its additional fuel requirement) from the regression equation. For example, a car that travels 7 and 8 km/L at normal condition will move only 5.5 and 6.4 km/L in a congested traffic condition respectively.

The mean of vehicles km/L with in a regular traffic flow condition(x) is 8.3 that vary from the mean by 4.6 km, and 6.7 km/L during a congested traffic environment(y), with its variance of 4 km from vehicle to vehicle due to their fuel efficiency. As a result, in order to reach the average distance (8.3 km/L), obviously additional fuel (0.24 litters) will require for 1.6 kilometers, that is, 1.24litters / 8.3km on average.

As it is clearly stated in the table (see appendix-8), most vehicles, from 82 respondents, 39 (47.6%) are traveling between 35 to 59 kilometers per day. Vehicle's daily average fuel consumption obviously affected as the expected distance that would have been moved per litter decreased from 8.3 to 6.7 km/L, to which additional litter of fuel required. As it is already found that high traffic flow take place with in 6 hours (one-fourth) of 24 hours (6:30 – 9:30 a.m. and 4:30 – 7:30 p.m.), the average fuel wasted per vehicle per day can be estimated or predict by using the following derived formula from a given statistics above, keeping other extraneous variables constant (drivers skill and landscape).

$$\textbf{Fuel wasted /vehicle/day} = \frac{(\text{“x” value} - \text{“y” value}) \pm d\ (1\ \text{litter})}{6.7\ \text{km/L}} * \frac{(\ tdt/d) * 0.25}{6.7\ \text{km/L}}$$

**Where:**

**“x” value**: is the number of kilometers traveled per litter in a normal traffic flow.

**“y” value**: is the number kilometers traveled per litter in a congested traffic condition that computed from the regression equation.

**±d**: is a correction value that minimizes the influence of vehicles that deviate from the sample mean of “y” due to their fuel consumption efficiency. **+d**: if the result of “y” value is less than the mean of (y) or 6.7 km/L, the difference (6.7 – the result) should be added on (“x” value – “y” value), and **-d**: if the result of “y” value is greater than the mean of (y), the difference (the result – 6.7) should be subtracted from (“x” value – “y” value).

**tdt/d:** Is vehicle's total distance traveled per day (km).

**0.25**: Is proportion of high traffic volume of a day (6/24 hours) in which traffic congestion is occurring.

Table 4.6 Sample of congestion impact on vehicles fuel consumption

| No. | "x" value (Km/L) | "y" value (Km/L) | ("x" –"y") | ±d | ("x"–"y") ±d | tdt/d | Additional fuel (vehicle/litter/day) |
|---|---|---|---|---|---|---|---|
| 1 | 4 | 2.75 | 1.25 | +3.95 | 5.2 | 40,50,60 | 1.17, 1.47, 1.74 respectively |
| 2 | 5 | 3.67 | 1.33 | +3.03 | 4.36 | 40,50,60 | 1, 1.24, 1.46 respectively |
| 3 | 6 | 4.6 | 1.4 | +2.1 | 3.5 | 40,50,60 | 0.8, 1, 1.17 respectively |
| 4 | 7 | 5.5 | 1.5 | +1.2 | 2.7 | 40,50,60 | 0.60, 0.8, 0.90 respectively |
| 5 | 8 | 6.43 | 1.57 | +0.27 | 1.84 | 40,50,60 | 0.41, 0.52, 0.61 respectively |
| 6 | 9 | 7.35 | 1.65 | -0.65 | 1 | 40,50,60 | 0.22, 0.3, 0.33 respectively |

Source: (Sample survey, 2010)

Congestion has an impact on vehicles fuel consumption. However, the impact is relatively different from vehicle to vehicle due to their efficiency. For illustration, let us take one example from the table-4.6 above.

Suppose that a car is consumed 1 litter of oil to run 4 kilometers in a smooth traffic condition, it can run only 2.75 ("y"= -0.932 + 0.92 (4)) in a congested traffic condition which is diverge by 1.25. Because it runs below the mean (6.7 km), the difference from the mean is 3.95 km (6.7 – 2.75) is added on ("x" –"y") values (i.e. 3.95 km +1.25 km) so as to minimizes the influence of some vehicles that deviate from the sample mean of (y) due to their fuel consumption efficiency (e.g. less than 6.7 km). As a result, it will be 5.2 km multiplied by 1 litter and divided to 6.7 km give us 0.78 litters. In addition, the rate is directly proportional to the daily total distance of a vehicle and proportion of high traffic volume of the day. For this case 40 km, multiplied by 25% (6/24 hrs) respectively, and then divided by 6.7 km give us 1.5. Lastly, 0.78 litters multiply by the rate 1.5 will result in **1.17** litters of additional fuel per day. The consumption is proportional to the vehicle's daily distance traveling (e.g. if 50 km/day, 1.47 litters of fuel waste as shown in the table-4.6 above).

From this, it is possible to say vehicles that travel more distance per litter in a regular traffic flow (efficient) is less affected than these traveled less kilometers, with the same daily total distance coverage, and vice-versa. The second point here is that the extent of the impact is directly related to the total distance traveling per day: that is vehicles that traveled more distance per day along the road, will lost more fuel (as total distance times 0.25) will be high.

### 4.7 Respondents Suggestion on Congestion Relief Strategies

Respondents were asked an open question to give their opinion on possible strategies that can solve traffic congestion. From all respondents collected (246), 104 were stated their view which match with what most authors suggested in chapter-two above, and presented from the most to the least as follows.

- ☛Increasing road network coverage: increase road capacity
- ☛Introducing mass transit: decrease traffic volume and increase mass traveling
- ☛Applying flexible work schedule: different starting and ending work schedule
- ☛Ensuring effective parking management: sufficient parking areas and the like
- ☛Ensuring good traffic management: modern and skilled traffic police
- ☛Introducing effective land use management: arranging residence, market and working place near to each other
- ☛Discourage car ownership: using high tax on luxurious automobiles
- ☛Ensuring technical fitness of vehicles every time
- ☛Managing an informal on-street trade
- ☛Participating private sectors in the transport systems, and
- ☛Doing more research on traffic management of the city

## 4.8 Summary

To day, congestion is imposing a great problem on cities growth of the world. Among others, long travel time, and waste of fuel. Despite this, a few researches, mostly in developed countries have done on traffic congestion that focused on different variables, like its impact on operating cost, and delay.

Nevertheless, they did not explain how it could affect vehicles fuel consumption in details. The aim of this paper is to assess the impact of vehicles traffic congestion from Total to Ayer-Tena route. Both probability and non-probability sampling techniques were applied and 270 respondents were drawn from different groups of the societies, as well as documents were collected from different transport organizations.

It has found that traffic congestion caused by many reasons, such as traffic volume exceeds road capacity; fixed work schedule, inefficient public transport, and poor urban land-use plan are the main shortage of the supply side though travel demand is increasing in time. Most journeys along the road are from various peripheral areas of the city to the core areas mainly for daily work and market purposes. Concerning the trip length, peoples are traveling between 6 and 10 km per day on average interval, and most of which are making in 6:30 – 9:30 a.m. and 5:30 – 7:30 p.m. Thus, traffic is highly congested with in these peak periods.

In Addis Ababa, the proportion of high occupancy vehicles is very low. The volume of vehicles population is increasing radically. For instance, the present vehicles population will be doubled after 6.3 years. The disturbing is not only for its large numbers, but also for their low occupancy, most of which are small size personal and private vehicles. Regarding to the road network coverage of the city, between 2006 and 2009, the total road length in the city increased by 564 km (25.1%), that is from 2,250 to 2814 km. Gravel road takes the large proportion (54.5%), and nearly a quarter (23.2%) is arterial roads.

However, it is slow-moving in contrasting with annual vehicles population growth. Vehicles are consuming more fuel in a congested traffic environment than in a free flow condition although its extent is varying from vehicle to vehicle due to their fuel efficiency and daily total distance they are traveling.

Moreover, traffic congestion affect travel time or delayed vehicles and passengers. It is 3 and 5 minutes per vehicle and passenger per trip respectively. Specifically, the situation is severe at Total intersection.

To sum up, even if the causes and its relief strategies are vary from area to area, congestion problem can be mitigated through different strategies, such as:

A. Apply flextime working schedules

B. Improve capacity of roads

C. Improving public transport

D. Experiencing adequate parking arrangements, and

E. Implement transit-oriented development and improved access management

# CHAPTER FIVE

# CONCLUSIONS AND RECOMMENDATIONS

## 5.0 Introduction

Main ideas of the finding are going to be concluded. Some possible interventions are forwarded and the core point of the study summarized.

## 5.1 Conclusions

Regarding to the current traffic flow and causes of vehicle congestion on this road, the survey found that on average interval passengers are traveling from 6 to 10 km per day on the road for different reasons, most extensively for work and market. Travel demand is reaching peak between 6:30 – 9:30 a.m. and 5:30 – 7:30 p.m. and relatively drop down (low demand or off peak) between 9:30 a.m. to 3:30 p.m. and 7:30 p.m. to 6:30 a.m. When looking at vehicles, most cars are so old that are between the age of 21 & 30 years, which are technically unfit, and most of them are small in size, 72% (119,468). Medium size public transports that have 30 and above seats are minimum in number, account 1.2% only from the total vehicles population of the city that leads to an imbalance between traffic volume and an existing infrastructures. Despite this, in the coming ten years (2020), the total number of vehicles predicted to reach to 486,278 (159.4%), with annual 29,879.5 (1.6%) incremental. The current number will be doubled with in 6.3 years from now (2010) of which most private and small personal vehicles will comprise the large share.

Congestion is occurred regularly and the major factor for congestion problem along the route are an imbalance between the current vehicles volume (high traffic volume) and road capacity, fixed work schedule, unavailability of public transport, and poor land-use planning.

Pertaining to the road network coverage of the city, from 2006 to 2009, the total road length in the city is increased by 25.1% (564 km) of which greater than half is gravel road (54.5%), and nearly a quarter (23.2%) is arterial roads. Though it is increasing from year to year, the proportion of arterial from all roads is only 652km by 7metres width in 2009 that is slow moving in contrasting with vehicles population growth.

With reference to the parking condition on this road, on-street vehicle parking condition is not a great factor or obstacle for smooth vehicle flow. On-street parking is prohibited on principal arterial roads or high ways like Total – Ayer Tena road in specific. However, evidence from Transport Office indicates that there are some factors that affect parking supply or space provision, such as constructions along the road sides and road maintenance. Nevertheless, there is no clear-cut policy and efficient mechanism that handle parking problem immediately. On other hand, parking charge of vehicles is directly related to their size and duration of stays irrespective to the traffic volume of a given area.

Traffic congestion has an influence on vehicles' daily fuel consumption and travel time (delay). It consumes more fuel when vehicles traveling in a congested condition and its magnitude are directly related to the vehicle's efficiency or kilometers traveling per litter and total daily distance. In addition, on average, traffic congestion delaying 3 minutes per vehicle and 5 minutes per passenger per direction.

## 5.2 Recommendations

### 5.2.1 Improvement on the supply side

Capacity of transportation system in general and road network in specific is needed to expand, such as:

#### 5.2.1.1 Increase capacity of roads

Increase the coverage of roads (specially, arterial roads which have more capacity) through construction and improving the capacity of the existing intersection by widening their entrance and exit radii and providing exclusive lanes for large vehicles that enable them to turn easily, and increasing the current lanes by shifting the reservations areas to the existing road will have appositive impact in mitigating traffic congestion.

#### 5.2.1.2 Improved Public transport

As from different countries experiences, efficient public transport is one and most important than others in solving traffic congestion by shifting traffic from automobile to a mass transit. Introducing high occupancy vehicles or mass transit, like light rail, rapid

buss transit, which should be coupled with better management of the existing road network and traffic management will have a great role in improving the high mobility demand of the city.

### 5.2.2 Improvement on the demand side

Travel demand management is needed in reducing the potential increasing number of motorcycles through various mechanisms, like, high import tax on luxury automobiles, car registration and owner fees, different petrol prices for public and private vehicles, high parking fee, parking prohibition, and time staggering of offices, should be implemented in general, and particularly the following intervention should be implemented.

#### 5.2.2.1 Adequate parking arrangements

Good and clear parking policy is essential element of any urban transport plan. Parking management: on and off-street parking management is very relevant in maintaining a smooth traffic flow. For Addis Ababa city, the following measures are essential in alleviating congestion.

A. *Provision of adequate supply*: There should be a trade-off between the space supplied and demand, depending on geographic conditions (sub-urban and core areas).

B. *Implement regulation efficiently*: Increase enforcement of regulations, particularly during peak periods, but insure that enforcement is friendly and fair.

C. *Variable parking price system*: is valuable in managing vehicles parking in an area where there is high traffic volume by:

- ✓ Adjust rates as needed to maintain optional utilization (i.e. 85% peak occupancy).
- ✓ Structure rates to favor short-term uses in high traffic areas and encourage longer-term parkers to shift to other locations.
- ✓ Provide special rates to serve appropriate uses, such as for evening and weekend events.

D. *Peak management*: Special efforts should be made to deal with peak-demand, like: reduce on-street time limits (e.g., 1-hour to 40 minutes) where needed to increase turnover. Specifically:

- ✓ Limit on-street parking of large vehicles (e.g., vehicles over 22 feet long or trailers) to ease traffic flow and discourage use of public parking for storage of commercial vehicles.
- ✓ Prohibit on-street parking on certain routes at certain times (such as on arterials during rush hour), to increase traffic lanes.

E. *User information*: Motorists should have information on their parking and travel options.

#### 5.2.2.2 Improve land-use planning

Travel demand has a direct relation with congestion. In Addis Ababa, most people are living at sub-urban in order to take the advantage of low land price and moving to the center of urban area for work. As a result, integrated land-use and transportation planning strategies should be formulated and implemented, like land-use controls (zoning), growth management restrictions or urban growth boundaries, reducing travel: gathering residential and commercial buildings near to a transit center (transit-oriented design) that favors transit so that use of personal automobile will be decreased, and incentives for high-density development areas through taxation policy.

Improved access management by arranging shops together to improve access for shoppers compared with the same shops sprawled along a highway can minimize travel and reduce congestion.

#### 5.2.2.3 Ensure flexible work schedule

To overcome congestion problem, flextime work schedule is one strategy, which allow different working time for daily people work. For example, starting at 10:00 a.m. and ending at 7:00 p.m. and so on will improve the current uni-directional travel demand.

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Appendix-1 Questioner and Interview

***Ethiopian Civil Service College***

***Questioner for passengers along Total to Ayertena Street***

The aim of this question is to assess the impact of vehicle congestion on Total to Zenebwork route on the travelers and fulfill the requirement for award of Master's degree in urban management.

I hope that you will give true information that a precious input for this work. Please, be informed that your information will kept secretly. Thank you for your all cooperativeness and kindness in advance.

**Instruction:** Put or mark "**x**" for a question, which required one choice, and for others ranks as 1, 2, 3…. in each box ☐

**Occupation:** Employer ☐ Own business ☐ Other ☐

**I. Question related to vehicle traffic flow characteristics through the Street**

For what purpose most frequently you traveled along the Street.

a) For job ☐ d) for shopping ☐

b) For education ☐ e) any other, specify_____

c) For recreation ☐

2. On average, how many kilometer(s) you are traveling in a day?___Km(s) per day.

3. In which hour of the day you mostly make a trip.

From___to ___ and from___to ___hour of the day.

4. To which direction most frequently you make a trip.

a) From center of the town to Ayertena and other areas via Total-Zenebwork road ☐

b) From other peripherals area to the center of the town via Zenbework-Total road ☐

5. Have you come across with vehicle congestion in your traveling?

a) Yes ☐ b)☐

6. How do you see the current vehicle traffic flow along the street?

a) Very high Congested ☐ d) Low Congestion ☐

b) Congested ☐ e) No Congestion ☐

c) Medium Congested ☐

**II. Question related to the causes of vehicle traffic congestion**

7. If your answer to the above is "a" or "b", rank the following causes of vehicle traffic congestion on the road according to its role:

a. Imbalance between the vehicles volume and road capacity ☐

b. Illegal on-street vehicle parking, boarding and alighting ☐

c. Inflexible work schedule of people ☐

d. Un-integrated land use ☐

e. Unavailability of mass transit ☐

f. Traffic accident ☐

g. Poor vehicle condition ☐

h. lack of transparent & good parking service delivery system ☐

i. Informal on-street trade ☐

j. If there is any other _____

_____

_____

**III. Question related to Congestion relief strategy**

8. What are the possible strategies that can solve traffic congestion? Please, specify them according to their significances.

_____

_____

_____

***Ethiopian Civil Service College***

***Questioner for motor vehicle drivers along Total to Ayertena Street.***

The aim of this question is to assess the impact of vehicle congestion on Total to Ayertena route on the travelers and fulfill the requirement for award of Master's degree in urban management.

I hope that you will give true information that a precious input for this work. Please, be informed that your information will kept secretly. Thank you for your all cooperativeness and kindness in advance.

**Instruction:** Put or mark "**x**" for a question that required one choice and rank for others in ☐

**I. Question related to the Current traffic flow**

1**.** Vehicle mode

a. Personal/ private vehicle ☐ c. Bus ☐

b. Taxi ☐ d. Freight ☐

2. Vehicle's carrying capacity. _____

3. How old is it? _____ years.

4. Is there vehicle congestion along the street?

a) Yes ☐ b) No ☐

5. How do you see the current vehicle traffic flow along the street?

a) Very high Congested ☐ d) Low Congestion ☐

b) Congested ☐ e) No Congestion ☐

c) Medium Congested ☐

**II. Question related to the causes of vehicle traffic congestion**

6. Rank the following causes of vehicle congestion on the road according to its role.

a. Imbalance between the vehicles volume and road capacity ☐

b. Illegal on-street vehicle parking, boarding and alighting ☐

c. Inflexible work schedule of people ☐

d. Un-integrated land use ☐

e. Unavailability of mass transit ☐

f. Traffic accident ☐

g. Poor vehicle condition ☐

h. lack of transparent & good parking service delivery system ☐

i. Informal on-street trade ☐

j. If there is any

_____

_____

**III. Question related to the impact of vehicle congestion on vehicles fuel consumption**

6. How many kilometers per litter fuel your vehicle consume on average when traveling during no Congestion along the street? _____ kilometers/litter

7. How many kilometers per litter fuel your vehicle consume on average during Congestion when traveling along the street? ____ kilometers/litter

8. How long do you traveled in the day on average on this route? ____ Kilometers

**IV. Question related to Congestion relief strategy**

9. What are the possible strategies that can solve traffic congestion? Please, specify them according to their significances.

_____

_____

_____

## Interview questions for traffic Police

1. How do you see the current vehicle traffic flow on the road?

_____

_____

_____

2. How do you evaluate the existing road net work or design in respect to the vehicle congestion?

_____

_____

_____

3. How do you evaluate the current on-street parking management regarding its relation to the congestion?

_____

_____

_____

4. From your experience, what are the causes for vehicle congestion along this route?

_____

_____

_____

5. How do you evaluate the general Vehicle Traffic Congestion conditions on this road?

_____

_____

_____

6. Would you state some possible Traffic Congestion relief strategy?

_____

_____

_____

**Thank you**

Appendix-2 Summary of Prior Research on Traffic Congestion

| No | Country & year of publication | Title of the research | Finding | Suggestion | Strength | Weakness |
|---|---|---|---|---|---|---|
| 1 | Chicago-Philadelphia America (2003) | *"Urban Traffic Congestion to Busines* | Elongate travel, increase operating costs (just-in-time) products & decrease productivity via in accessibility | -Mix technology<br>-Production function model | It identify congestion cost of business area in details. | It did not state the causes & mitigation strategy in deep. |
| 2 | Hanoi-Vietnam (2003) | *"Urban Traffic Congestion"* | Economic development is the main caus congestion.<br><br>Road constructions attract other traffic. | -Public transport<br>-Capacitate roads<br>-Travel demand management<br>-Integrated land use | Identify the factor & state the solution clearl | It did not indicate how the new development around road can be solved. |
| 3 | Lagos-Nigeria (2009) | *"Effect & Measure of Road Traffic Congestion"* | Social & economic, road, vehicle, & accident are main factors. | -Transport coordinatio<br>- Road capacity expansion, & demand management | Illustrated the factors & intervention clearly. | It lost to focus on impact of congestion in differen dimensions. |

Source: (Weisbrod et. al, 2003; Joshua et. al, 2009)

Appendix-3 Summary on Functional Classification of Urban Roads

| **Function** | **Road hierarchy** | | | |
|---|---|---|---|---|
| | **Principal arterial roads** | **Sub-arterial roads** | **Urban collectors Streets** | **Urban local streets** |
| | • traffic movements is a primary function<br>• longer distance traffic movements<br>• line heave public transport task<br>• primary freight and dangerous goods routes<br>• regional cycle movements (off road)<br>• Greater than 20,000 vehicles per day;<br>• Greater than 5,000 bus passengers per day;<br>• Sidewalks on both side | • connections between local areas and arterial roads<br>• connections for through traffic between arterial roads<br>• access to public transport<br>• through movement of public transport<br>• regional – local cycle movements (off road)<br>• 8,000 to 20,000 vehicles per day;<br>• 1,500 to 5,000 bus passenger per day;<br>• No “Stop” signs; main intersections controlled by traffic signals; | • carry traffic having a trip end within the specific area<br>• direct access to properties<br>• access to public transport<br>• local cycle movements<br>• 2,500 to 8,000 vehicles per day<br>• Less than 1,500 bus or streetcar passenger per day<br>• Signalized intersections at arterial roads<br>• Sidewalks on both sides of the road | • direct access to properties<br>• pedestrian movements, at least one side of road<br>• local cycle movements<br>• Less than 2,500 vehicles per day;<br>• Low traffic speed; |

Source: (Eppell, Bunker, & Mcclurg, 2001, p: 6; City of Toronto, 2010)

Appendix-4 Summary of vehicles counting method. Date: 4/01/2010

| Mode of transport | Period of count | | | | | | | EVPA/ hr | ETPTA/hr |
|---|---|---|---|---|---|---|---|---|---|
| | Morning time (7:00 – 8:00 am) | | | | Afternoon (2:00 – 3:00 pm) | | | | |
| *Passenger transport* | Vehicles counted/hr | Capacity[1] (Passenger) | Estimated PV/v/hr (% of average capacity) | TPT/hr | Vehicles counted/ hr | Estimated PV/v/hr (% of average capacity) | TPT/hr on average interval | | |
| Large Bus | 42 | 60 – 80 (70) | 100% | 2940 | 36 | 50 – 75% (40 & 60) | 1440 -2160 | 39 | (39*57) 2223 |
| Medium Bus | 162 | 45 – 60 (52) | 100% | 8424 | 137 | 50 – 75% (26 & 39) | 3562 - 5343 | 149 | (149*39) 5811 |
| Minibus taxis | 572 | 4 – 12 (8) | 100% | 4576 | 498 | 50 – 75% (4 & 6) | 1992 -2988 | 535 | (535*6) 3210 |
| Private car | 483 | 3 – 5 (4) | 25% | 483 | 367 | 25% | 367 | 425 | (425*1) 425 |
| *Freight*[2] Large size | 12 | 1 -2 (2) | nil | nil | 22 | nil | nil | 18 | nil |
| Medium size | 48 | 1 -2 (2) | nil | nil | 66 | nil | nil | 57 | nil |
| Small size | 62 | 1 -2 (2) | nil | nil | 82 | nil | nil | 72 | nil |
| Grand Total | 1,381 | - | | 16,423 | 1,208 | - | 7,361 – 10,491 | 1,295 | 11,669 |

Source: (Field survey, 2010)

[1] Average of different capacities
[2] Excluding the driver

Appendix-5 Summary of sample survey on vehicles traffic characteristics

| No | Variables | Response rate in percentage (%) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Daily passenger average trip length (Km/day) | <2 | 3 - 5 | 6 - 10 | 11 -15 | 16 - 20 | 21 - 25 | 26 - 30 | 31-40 | > 40 | **Total** |
| | | 1 | 4 | 56 | 40 | 25 | 13 | 13 | 8 | 1 | 159 |
| 2 | Travel time | 6:30 – 9:30 a.m | 9:30 a.m – 12:30 p.m | 12:30 – 3:30 p.m | 3:30 – 5:00 p.m | 5:30 – 7:30 p.m | 7:30 – 11:30 p.m | Missed | | | |
| | | 93 | 4 | 5 | 15 | 90 | 7 | 1 | | | 215 |
| 3 | Vehicles age (Years) | <10 | 10-20 | 21-30 | 31-40 | 41-50 | >50 | Missed | | | |
| | | 5 | 14 | 34 | 18 | 6 | 2 | 3 | | | 82 |
| 4 | Extent of congestion | Very high | Congested | Medium | Low | No | Missed | | | | |
| | | 93 | 140 | 5 | 2 | 1 | 0 | | | | 241 |
| 5 | Capacity (in seats & quintals) | <6 | 6 - 12 | 13 - 29 | 30 - 44 | > 44 | Missed | | | | |
| | | 25 | 34 | 10 | 4 | 9 | 0 | | | | 82 |
| 6 | Trip purpose | Work | Education | Recreation | Market | If any | Missed | | | | |
| | | 94 | 25 | 6 | 31 | 3 | 0 | | | | 159 |
| 7 | Travel direction | From different peripheral area to CBD via Ayertena -Total | From the CBD to different peripheral Areas via Total - Ayertena rout | Missed | | | | | | | |
| | | 84 | 75 | 0 | | | | | | | 159 |
| 8 | Category of vehicles | Private | Taxi | Bus | Truck | Missed | | | | | |
| | | 36 | 22 | 16 | 8 | 0 | | | | | 82 |
| 9 | Presents of congestion | Yes off course | No at all | Missed | | | | | | | |
| | | 238 | 3 | 0 | | | | | | | 241 |

Source: (Sample survey, 2010)

Appendix-6.a Manual delay measurement using queue length

**Street**: Total to Ayertena (Total intersection). Counted by: Yared Haregewoin. Date 08/03/10

Length of **QUEUE** at start of period: 48 meters. Counting interval: 2minutes

| Interval # | Stopped (Sv) Sum | Leaving (Lv) Sum | Vehicles remaining in queue | Vehicles passed on opposite direction | Queue length at the end of interval | Estimated passengers in a queue | Estimated passengers Passed on opposite side |
|---|---|---|---|---|---|---|---|
| 1 | 36 | 8 | 28 | 7 | 84 | 311 | 78 |
| 2 | 33 | 11 | 22 | 9 | 67 | 207 | 97 |
| 3 | 26 | 7 | 19 | 5 | 58 | 194 | 38 |
| 4 | 20 | 9 | 11 | 6 | 34 | 178 | 52 |
| 5 | 14 | 7 | 7 | 5 | 24 | 86 | 63 |
| 6 | 9 | 6 | 3 | 4 | 11 | 19 | 34 |
| 7 | 7 | 5 | 2 | 7 | 5 | 8 | 25 |
| 8 | 9 | 6 | 3 | 4 | 11 | 34 | 8 |
| 9 | 12 | 8 | 4 | 6 | 14 | 51 | 72 |
| 10 | 5 | 5 | 0 | 4 | 0 | 0 | 12 |
| **Total** | **171** | **72** | **99** | **57** | **308** | **1088** | **479** |

Source: (Field survey, 2010)

Appendix-6.b Manual delay measurement using queue length

**Street**: Total to Ayertena (Zenbwork intersection) **by: Yared** Haregewoin. Date 10/3/0

Length of QUEUE at start of period: 36 meters. Counting interval 2minutes

| Interval # | Stopped (Sv) Sum | Leaving (Lv) Sum | Vehicles remaining in queue | Vehicles passed on opposite direction | Queue length at the end of interval | Estimated passengers in a queue | Estimated passengers Passed on opposite side |
|---|---|---|---|---|---|---|---|
| 1 | 16 | 5 | 11 | 3 | 32 | 118 | 47 |
| 2 | 13 | 6 | 7 | 5 | 24 | 84 | 29 |
| 3 | 11 | 7 | 4 | 4 | 15 | 58 | 28 |
| 4 | 10 | 4 | 6 | 4 | 24 | 78 | 43 |
| 5 | 14 | 6 | 8 | 6 | 26 | 102 | 52 |
| 6 | 12 | 6 | 6 | 4 | 20 | 63 | 16 |
| 7 | 9 | 4 | 5 | 7 | 18 | 48 | 37 |
| 8 | 7 | 5 | 2 | 6 | 7 | 31 | 32 |
| 9 | 11 | 5 | 6 | 4 | 18 | 86 | 12 |
| **Total** | **103** | **48** | **55** | **43** | **184** | **668** | **296** |

Source: (Field survey, 2010)

Appendix-6.c Manual delay measurement using queue length

**Street**: Ayertena to Total (Ayertena intersection). **By**: Yared Haregewoin. Date12/03/10

Length of **QUEUE** at start of period: 41 meters. Counting interval 2minutes

| Interval # | Stopped (Sv) Sum | Leaving (Lv) Sum | Vehicles remaining in queue | Vehicles passed on opposite direction | Queue length at the end of interval | Estimated passengers in a queue | Estimated passengers Passed on opposite side |
|---|---|---|---|---|---|---|---|
| 1 | 29 | 12 | 17 | 9 | 52 | 222 | 112 |
| 2 | 21 | 10 | 11 | 7 | 36 | 173 | 97 |
| 3 | 17 | 9 | 8 | 5 | 28 | 106 | 49 |
| 4 | 13 | 7 | 6 | 4 | 26 | 89 | 27 |
| 5 | 14 | 6 | 8 | 5 | 29 | 99 | 42 |
| 6 | 11 | 7 | 4 | 2 | 16 | 62 | 23 |
| 7 | 12 | 5 | 7 | 4 | 20 | 132 | 68 |
| 8 | 15 | 8 | 7 | 3 | 26 | 119 | 17 |
| 9 | 11 | 8 | 3 | 4 | 11 | 26 | 38 |
| 10 | 9 | 5 | 4 | 3 | 14 | 73 | 14 |
| 11 | 12 | 6 | 6 | 5 | 22 | 81 | 51 |
| 12 | 8 | 7 | 1 | 3 | 3 | 148 | 69 |
| **Total** | **172** | **90** | **82** | **54** | **283** | **1330** | **607** |

Source: (Field survey, 2010)

Appendix-7 Congestion Indicators

| No. | Indicator | Description |
|---|---|---|
| 1. | Vehicle traffic flow characteristics.<br><br>-Trip purpose, trip time, & traffic compositions.<br><br>-Volume of vehicles or persons traveled in a congested time | -At what time most traveling is making.<br>-For what purpose that the trip is making.<br>-What are the types or compositions of traffic.<br><br>-Number of vehicles or persons that travel in peak-period under congested conditions. |
| 2. | Reason for congestion<br>-Recurrent<br>-Non recurrent | It occurs regularly bases: on a daily, weekly or annual, that can be easier to manage.<br><br>It occurs irregularly (sometimes) due to accidents, special events, road constructions and the like events. |
| 3. | On-Street parking<br>Supply, price and regulation | Prohibit on-street parking on certain routes, during rush hour so as to maintain the smooth traffic flow, and parking regulation based on flexible rate and time, and favor priority vehicles: like emergency, public transport service, etc. |
| 4. | Road Capacity<br>Roadway/ level-of-service (LOS) | Congestion intensity on a particular roadway or at an intersection, rated from A (un-congested) to F (extremely congested). |
| 5. | Congestion Impact<br>Hours of delay<br>Excess fuel consumption. | -Hours of extra travel time due to congestion.<br>-Additional fuel consumption due to congestion. |

Source: (Litman, 2005 cited in VTPI, 2008; 2009)

Appendix-8 Vehicles average distance travelled per day in kilometres

| <35 | 35-59 | 60-89 | 90-119 | 120-149 | 150-179 | 180-200 | >200 | Total |
|---|---|---|---|---|---|---|---|---|
| 18(22%) | 39(47.6%) | 13(15.8%) | (6.1%) | 4(4.9%) | 2(2.4%) | 1(1.2%) | 0(0%) | 82(100%) |

Source: (Sample survey, 2010)

Appendix-9 Future Vehicles population growth trends in A.A (2010 – 2020)

| Year | Vehicles population | Growth in % | Remark |
|---|---|---|---|
| 2010 | 187,483 | - | |
| 2011 | 217,362 | 15.94 | |
| 2012 | 247241 | 31.87 | |
| 2013 | 277,120 | 47.81 | |
| 2014 | 306,999 | 63.75 | |
| 2015 | 336,878 | 79.69 | |
| 2016 | 366,757 | 95.63 | |
| 2017 | 396,636 | 111.57 | More than double |
| 2018 | 426,515 | 127.51 | |
| 2019 | 456,394 | 143.45 | |
| 2020 | 486,278 | 159.40 | |

Source: (Addis Ababa Transport Branch Organization, 2010)

Appendix-10 Vehicles distance coverage per litter in different traffic condition

| Km/L in a normal Traffic(x) | Km/L in a congested Traffic(y) | Frequency (f) |
|---|---|---|
| 10 | 9 | 4 |
| 8 | 7 | 5 |
| 7 | 5 | 7 |
| 7 | 6 | 5 |
| 10 | 8 | 5 |
| 9 | 7 | 6 |
| 5 | 4 | 6 |
| 9 | 8 | 3 |
| 7 | 5.5 | 1 |
| 9.5 | 8.5 | 1 |
| 8.5 | 6.5 | 1 |
| 6 | 4.5 | 2 |
| 8 | 6.5 | 2 |
| 12 | 11 | 1 |
| 7.5 | 5.5 | 1 |
| 8 | 6 | 4 |
| 10.5 | 8 | 2 |
| 10 | 8.5 | 2 |
| 11.5 | 9.5 | 2 |
| 5.5 | 4 | 1 |
| 7.5 | 6 | 1 |
| 4 | 3 | 1 |
| 10.5 | 8.5 | 1 |
| 6 | 4 | 2 |
| 5 | 3 | 3 |
| 9 | 7.5 | 1 |
| 12 | 10 | 5 |
| 6 | 5 | 3 |
| 11 | 9 | 4 |

Source: (Field survey, 2010)